GEOLOGY *in its* RELATION *to* LANDSCAPE

JUNIUS HENDERSON

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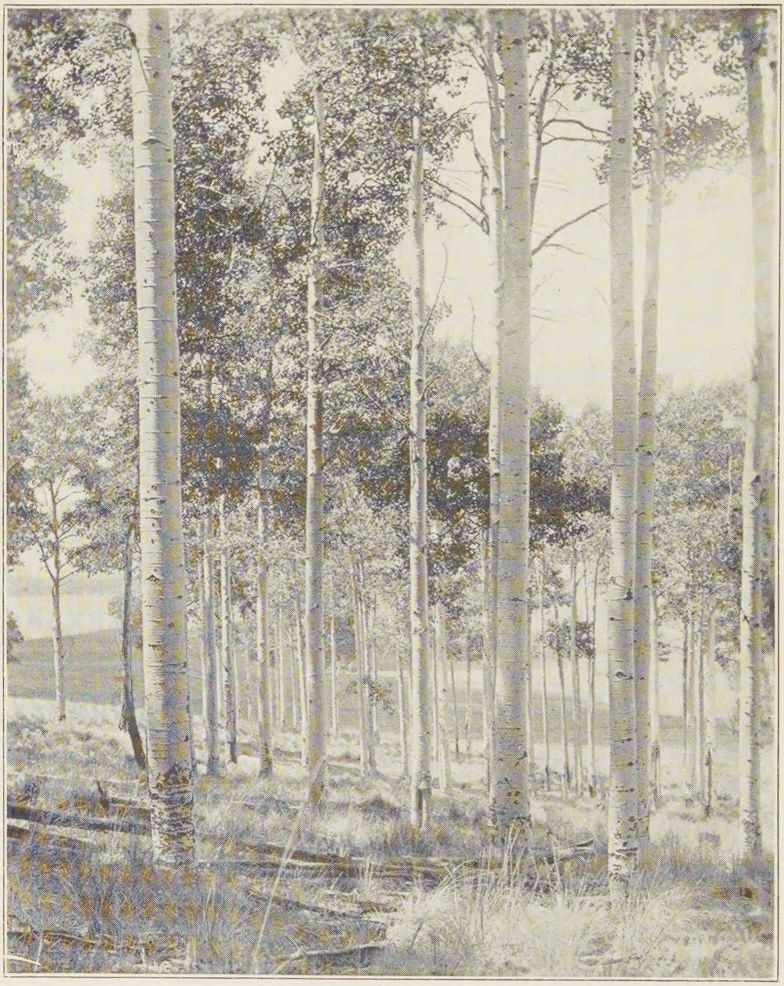

Aspens in Northern New Mexico, growing on soil derived from the decomposition of surrounding formations, on a slope prepared by erosion, hence an indirect result of geological processes.

Geology in its Relation

to

Landscape

BY JUNIUS HENDERSON

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DEDICATED

TO THE MEMORY OF THE
AUTHOR'S BELOVED WIFE

MRS. NELLIE BARTLETT HENDERSON

WHOSE NUMEROUS SUGGESTIONS AND KINDLY CRITICISMS HAVE HELPED TO RENDER THIS VOLUME MORE COMPREHENSIBLE TO THE NON-TECHNICAL READER. HER LIFE OF HELPFULNESS TO OTHERS CAME TO A CLOSE BEFORE THE MANUSCRIPT REACHED THE PRINTER'S HANDS.

66494

To him who in the love of Nature holds
Communion with her visible forms, she speaks
A various language; for his gayer hours
She has a voice of gladness, and a smile
And eloquence of beauty; and she glides
Into his darker musings with a mild
And gentle sympathy that steals away
Their sharpness ere he is aware.

Bryant.

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Introduction

"Lovely indeed the mimic works of Art,
But Nature's works far lovelier."
COWPER.

EVERY landscape has a history to relate — a past, present and future — and bids us open the Book of Nature and read, thus to reach a higher appreciation of beautiful and inspiring scenery by learning something of the reasons for its existence. Each scenic view is the direct or indirect product of geological phenomena, processes or agencies. That this is true of some scenery is manifest as one stands in the presence of towering mountains, with their rocky pinnacles and yawning chasms (Figs. 1, 2). Perhaps not so instantly apparent to the uninitiated, it is just as true of the broad valley, with its gentle bordering slopes, or the plain, with its almost level expanse stretching away to the horizon (Figs. 83, 87). Such things can exist only as a result of geological processes, operating for long periods. However, it must not be imagined that the analysis of topography or surface inequalities exhausts the subject, or even approaches its boundaries. Every element in the landscape bears some relation, be it proximate or remote, to the geology of the region. Even the vegetation shares in that relationship; rocks and soil on one hand and trees, shrubs and herbs on the other constantly acting and reacting upon one another. The microscopic bacteria assist in the decomposition of rocks and the preparation of soil for the higher plants. The lowly algae aid in the building up of great deposits of travertine (Figs. 7, 18), whose terraces are among the most striking scenic features of Yellowstone National Park and some other portions of the world. The trees, flowers and other vegetation that give to landscape its chief attraction, are enabled to thrive by conditions resulting from geological processes (Frontispiece), while in their turn the trees and other vegetation are themselves geological agencies. The soil upon which plants grow is a geological product. The distribution of plants is to a great extent governed by climatic conditions, which in turn depend largely upon geological phenomena, such as the distribution of land and water, mountain ranges, valleys and plains. The birds and butterflies, the cattle and sheep that enliven the landscape are indirectly under the control of geological conditions, because their presence or absence is so influenced by the character of the vegetation. The location of cities and the erection of farm houses and other works of man that so frequently make or mar the scene, are generally influenced more or less by geological phenomena, such as soil, streams, lakes, natural harbors, mountain ranges and passes, climate and the proximity of gold, silver, copper, coal, iron, lime, clay, building stone or other deposits of commercial and industrial importance. The location of pleasure and health resorts, where one may enjoy fine scenery as part of one's pleasure or health seeking, is partly determined by the geological environment.

Fig. 1 — "Towering mountains, with their rocky pinnacles and yawning chasms."

Fig. 2 — "Canyons carved little by little by the very streams now flowing through."

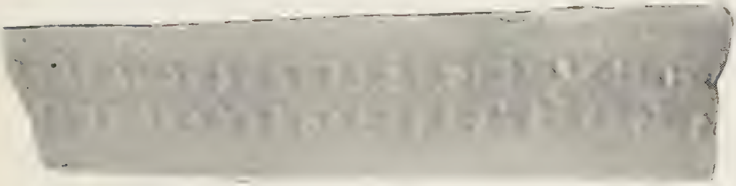

Fig. 3 — Fossil Amphibian footprints, Upper Carboniferous Age.

In order to correctly interpret the phenomena with which he must deal, the geologist has need of a broad knowledge of other branches of natural science. The botanist and zoologist need a broad understanding of many of the principles and larger facts of geology. Our enjoyment of the study of any branch of natural science, and our appreciation of natural objects and phenomena, must depend more upon knowing the relations of things to each other than upon knowing the things themselves. The greatest delight of the biologist comes from a knowledge of the relations of plants and animals to each other and to their whole environment. The greatest delight of the geologist comes from a knowledge of the relations of geological facts and principles to the whole environment, and a knowledge of the history of the environment as revealed in the rocks and the topography.

From the days of Egyptian and Grecian splendor the painter's brush and sculptor's mallet have been devoted to the imitation of the human figure and groups of figures. Only within the past century or so has landscape taken a prominent place in Art. Its possibilities are now apparent. Happy indeed the artist who can combine with the rare gift of transferring to canvas the pictorial qualities of landscape, an understanding of the processes by which it came into being, for how can he otherwise catch and properly interpret the spirit of the view?

As we observe a fine painting, how much more absorbing our interest if we know something of the artist and his methods; the various steps by which the painter wrought out the final result, a stroke of the brush here and a stroke there. Thus in Nature's art gallery we may read the history of the landscape, reconstruct its past and trace the various processes by which it reached its present beauty, a picture at all times in its history complete, though never finished. We may even pass beyond the present, and with some confidence predict its future—the changes that must inevitably be wrought by processes now in operation.

Geology is the geography of the past, as Lord Avebury has aptly expressed it. An eminent historian once said that "he who calls what has vanished back again into being, enjoys a bliss like that of creating." The wonderful "restorations" adorning the walls of great museums, displaying the artists' conceptions of the scenery of the past — the Carboniferous and Permian swamps, with a flora and fauna so different from that of today (Figs. 4, 5); the Mesozoic valleys, with their huge and grotesque dinosaurs, great pterodactyles flying overhead; the Mesozoic seas, with their plesiosaurs and ichthyosaurs pursuing their prey — these are not vain imaginings. The records in the rocks show unmistakably the general conditions of the region while the rocks were being formed, enabling the artist, with the aid of the geologist, to reconstruct the topography in a general way. The remains of the plants preserved in the rocks enable the artist, with the aid of the paleobotanist, to reconstruct the flora and with his mind's eye clothe the land with vegetation of types long extinct. The complete skeletons found in the rocks enable the artist, with the aid of the paleozoologist and anatomist, to reconstruct animals that long ago

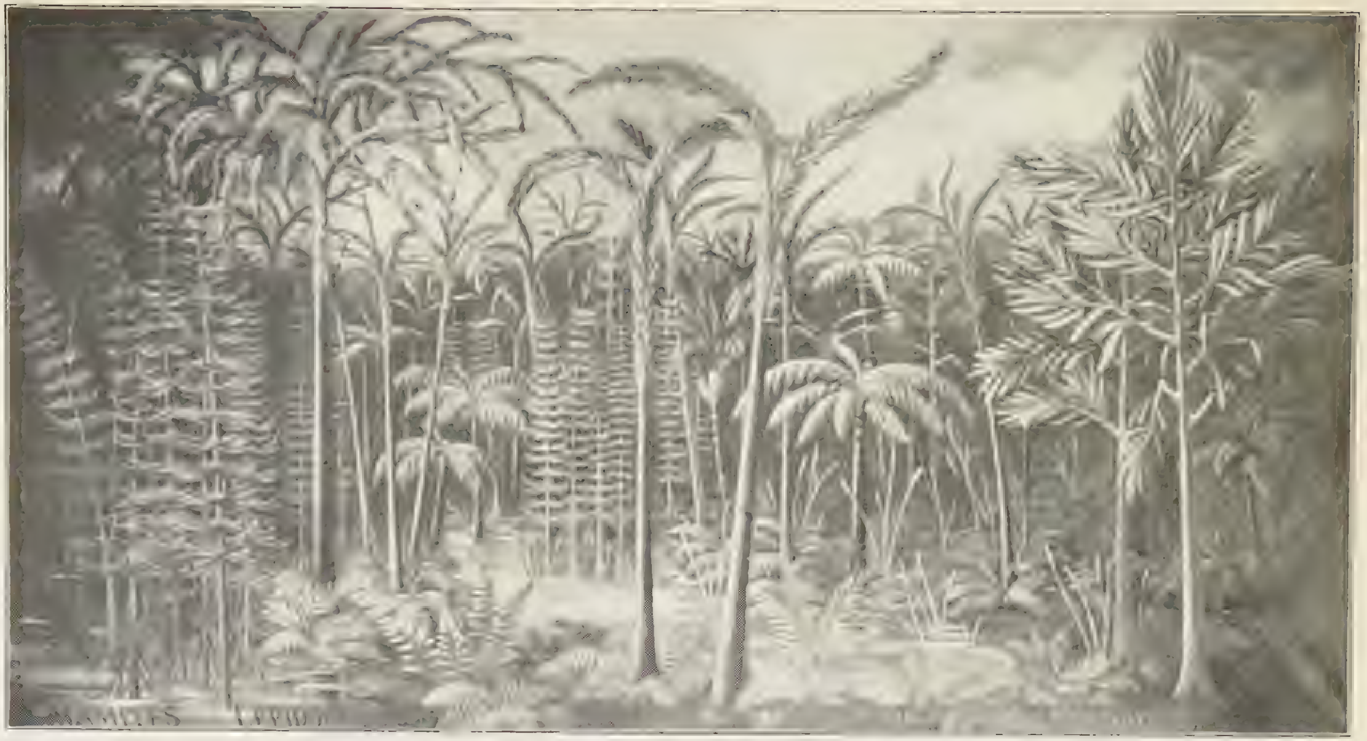

FIG. 1.—Ideal Carboniferous landscape. Republished by permission of Field Museum of Natural History.

roamed the land, swam the seas and glided through the air, and thus to repeople the scene with its former inhabitants. With all this information before him, he may somewhat accurately present to us a landscape of swamps in a region now arid, clothed with verdure now unknown, in which the extinct

> "Long-necked lizards basked and fought,
> And winged dragons ruin wrought."

A fascinating story is the one we read in the rocks, of the various stages in the development of the earth's surface and its inhabitants, leading up to their present state. Where the earliest fossil-bearing rocks have been upturned by the crumpling of the earth's crust and then exposed by erosion, we find a total absence of the types of plants and animals with which we are now most familiar. No trees or flowering plants adorned the land at that early period; no fishes swam the seas; no mammals roamed the continents; no birds winged their way through the air; there were no reptiles, no amphibians. Trilobites and eurypterids, long since extinct, then ruled the seas. Inarticulate brachiopods, now represented by an insignificant number of living species and individuals, constituted a very important element in the ancient faunas. In successive later formations we find the faunas and floras becoming more and more like those of today, until in the Tertiary rocks are found many genera and some species which are not yet extinct.

The rocks plainly inform us, by abundant and very definite evidence, that throughout the past ages conditions were constantly changing, ever so slowly to be sure, but ever so certainly. Mountains rose from the plains and then in the course of time disappeared. Continents repeatedly shifted their boundaries. Seas invaded the land and then retreated, reinvaded and retreated again, repeating this process over and over. With each change in climatic and physiographic conditions formations of different character were deposited. Hence we have alternating deposits of sandstone, limestone and shale, each telling a different story of its origin. Some formations teem with marine fossils, some are filled with land, fresh-water or brackish-water fossils, according to the conditions under which they were deposited. The difference in the character of these ancient formations has a very important influence upon modern scenery and is intimately related to the welfare of the human race. The sandstones provide building stone in abundance; limestones provide lime for plaster and other purposes; shales provide brick-making material; deposits of iron provide indispensable construction material; great deposits of coal make it possible to work the iron into shape for use. All these things enter into the construction of the buildings which have greatly altered the scenery of all civilized lands, and have made possible the architecture of our modern cities. So when our attention is arrested by a fifteen-story sky-scraper, we may truhtfully say that this was made possible by the geological processes which deposited these materials so long ago and afterwards tilted them up and exposed them where they could be obtained when needed. When the rank vegetation in certain regions during the Carboniferous and Cretaceous ages was

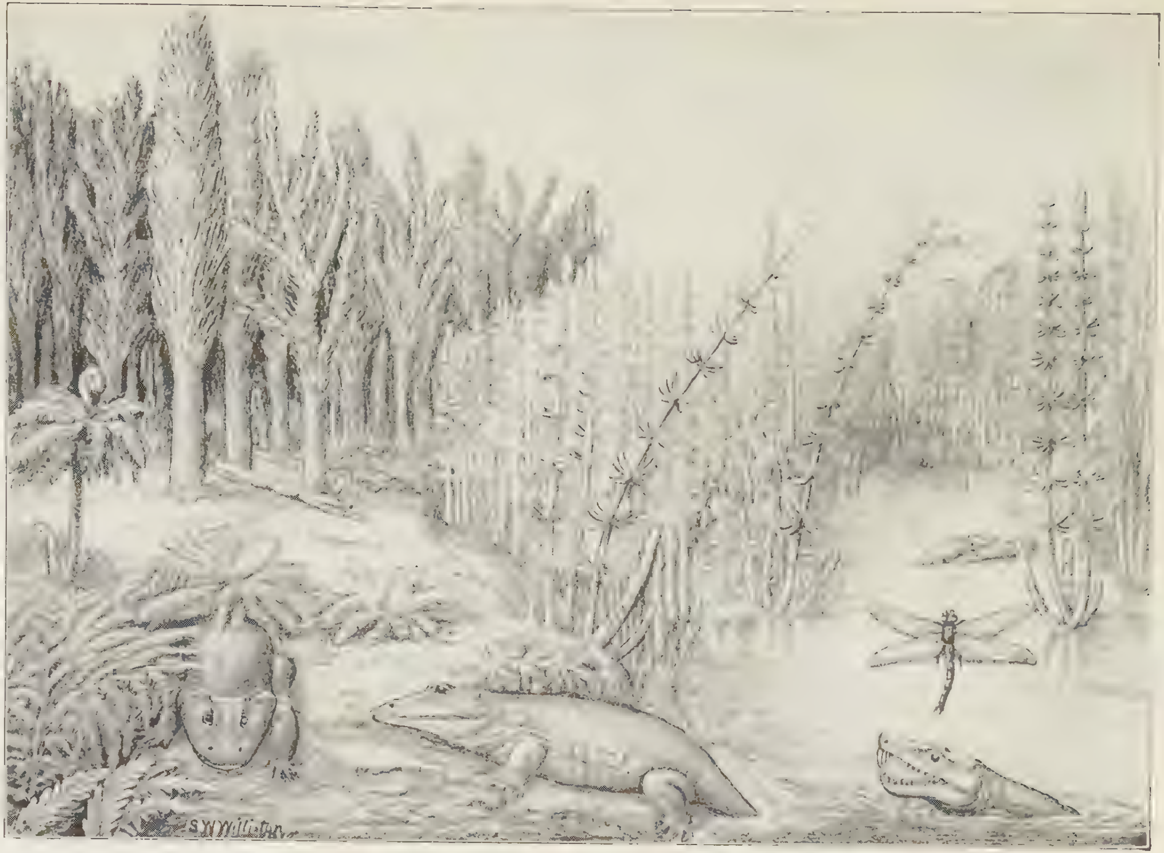

FIG. 5 — Ideal Permo Carboniferous landscape. Drawn by Professor S. W. Williston. Copyrighted. Republished by permission of The University of Chicago Press.

filling the ancient swamps with coal, it was preparing the way for modern civilization, with its densely packed cities, its steamships and its railways. Other deposits deep beneath the earth's surface have become available to man, through his industry and genius. His drills are penetrating the earth to a depth of seven thousand feet or more in the search for oil stored there long ago. His shafts are sinking many hundreds of feet below the surface in the search for the mineral wealth deposited there in by-gone ages.

Whether or not we see in all this a purpose to provide for the coming of man, it is surely wonderful to contemplate that all these things which make for the comfort, pleasure and progress of the human race, were prepared by Nature so abundantly when no man walked the face of the earth. Far back in pre-Cambrian time life appeared, but for long ages the environment remained unsuitable for man. As time passed, the fishes and frogs, the grains and grasses, the fruits and vegetables, the trees and flowers, the birds and cattle, and all other organisms needful to provide human beings with food and raiment, and to minister to their aesthetic tastes, appeared upon earth. Then, and only then, man appeared and assumed

> "dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over the earth, and over every creeping thing that creepeth upon the earth!"

The Reign of Law

> "It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us."
>
> CHARLES DARWIN.

> "In using the present in order to reveal the past, we assume that the forces in the world are essentially the same through all time; for these forces are based on the very nature of matter, and could not have changed. . . . The laws of the existing world, if perfectly known, are consequently a key to past history."
>
> JAMES D. DANA.

NOTHING comes by chance. Not always able to trace things to their proximate causes, perhaps never to learn the ultimate causes, we may yet rest assured that all things in the material world are governed by laws definite and certain in their operation, more inexorable than those of the Medes and Persians. Charles Darwin once referred to these laws as having been in the beginning "impressed on matter by the Creator." True, the wind seemingly "blowest where it listeth," yet in fact its most eccentric moods are in response to laws as definite as those which cause the apple, released from the bough, to fall to the ground; or guide the stars and planets in their courses; or keep the moon moving in its orbit with such precision that its phases and eclipses may be long foretold with scarcely a second's error.

In the physical world the reign of law is supreme. Fortunate is this, indeed, for the human race. Imagine a world not governed by dependable, unchangeable law! A world in which water cannot be trusted to run down hill, but wanders at will over hill and vale! A world in which seasons cannot be relied upon to come and go at their appointed times! A world in which plants and animals fail to reproduce their kind, but give birth to all sorts of bizarre objects! A world in which the farmer plants corn and raises thistles; sows wheat and raises rye! A world in which the magnetic needle refuses to guide the mariner in his true course or to assist the surveyor in establishing his boundaries! A world in which the laws of gravity suspend operation and permit objects to hop and float about in all directions! A world in which the sun and moon abandon their schedules and the planets leave their orbits and roam through space at random! Such a world is unthinkable and would be uninhabitable!

Everything on earth appears to change except those laws impressed upon matter in the beginning. It is by studying these laws and their effects as manifested at the present time that we may in a measure come to some sort of understanding of how the earth has been brought to its present condition and made a fit habitation for mankind.

In the infancy of geological science it was believed that the various changes in the earth's condition were the effects of sudden widespread and sweeping catastrophes. Long abandoned by science, that view still retains a strong hold upon the public mind. A traveller, coming suddenly upon the brink of the Grand Canyon of the Colorado, supposes that the awe-inspiring chasm, with all its windings and ramifications, is the result of some terrific cataclysm, in an instant rending the rocks to a depth of several thousand feet; or of some rushing deluge, which in a short time profoundly sculptured the earth's surface over hundreds of square miles. Standing upon a high point and viewing a great mountain system, with its multitude of peaks and deep gorges, he wonders at the fearful convulsions that must have shaken the earth from center to circumference, as those huge masses of rock were heaved to an altitude of fourteen thousand feet or more above the level of the sea.

Much more beautiful and wonderful is the modern idea, based upon a large accumulation of definite information, that these things were slowly wrought out by forces still in active operation all about us; that the canyons were carved little by little by the very streams now flowing through (Fig. 2), assisted by storms, frost and subaerial decomposition of the rocks; that the elevation of the mountain ranges has been so gradual as to be scarcely measurable; and that the process of mountain building and mountain destroying continues to the present day. These processes may be studied in actual operation in many regions, some of them in any region.

In past ages mud-flats formed at the mouths and in the valleys of streams in flood time, just as they do now. When the floods retreated, animals crossed the mud, leaving well-marked trails behind them (Fig. 3), as they do at the present time. Raindrops fell upon the mud, leaving their imprints, the direction of the "splash" often recording not only the rain, but even the direction of the wind (Fig. 6). Then the burning rays of the sun baked the mud and cracked it in all directions in geometric figures, as so frequently happens now-a-days (Figs. 8, 9). Then fresh flows of mud during the next flood covered the dried surface, filling the cracks, tracks and rainprints, preserving them for the wondering gaze of modern man, just as such deposits of mud are preserving such cracks, tracks and rainprints on this year's mud-flats, for future generations to behold. The mud of today will harden into rock, just as the mud of past geological ages has hardened. In the beds and along the shores of our modern lakes and streams, under favorable conditions, and even along the roadsides after a summer's storm, may be seen ripple-marks produced by the action of waves or running water (Fig. 10). In the rocks are found fossil ripple-marks produced in just the same way (Fig. 11). Fossil shells tell the same story that we read on modern beaches. The perfectly-preserved skeletons of saber-toothed tigers, ground sloths, mastodons, mammoths and other extinct animals from the asphalt beds of Rancho La Brea, California, represent victims that were trapped in the asphalt lake during Pleistocene time, just as rabbits, birds and other creatures are being trapped now-a-days in such lakes. Cross-bedding in the ancient rocks (Fig. 12) tells the same story that it tells in recent sandbanks whose deposition one may observe. So from a knowledge of all these and other every-day processes the student may mentally reconstruct and with his mind's eye gaze upon the essential features of landscapes long ago covered or partly eroded and carried away.

We are awe-stricken in the presence of such terrific exhibitions of volcano force as the Pelée eruption, or such earthquake devastation as that of Charleston, but these exhibitions are local and occasional. Much more important are Nature's operations in her gentle moods — the chemical and physical effects of flowing, dripping and percolating water and of the atmosphere; the slow bending and crushing of rocks; the making and transportation of soils; the formation and destruction of lakes; the shifting of river channels; the movements of glaciers; the gradual rise and fall of continents; all bearing testimony to the perpetual operation of the silent forces of Nature, constantly molding and remolding, fashioning and refashioning the old earth which in our ignorance we have sometimes considered the very embodiment of stability, as we have cried unto the "everlasting hills."

The opportunities for the study of Nature in her angry moods are few. Great catastrophes seldom occur, but the more gentle processes of Nature never cease. How much more of beauty there is in a natural object if we see in it a product of a system of laws in constant operation about us, bearing more or less intimate relation to other objects likewise resulting from the operation of law, instead of seeing in each an isolated product of chance. The solid rock, attacked by Nature's forces of destruction acting in accordance with inexorable law, disintegrates. Its debris is spread over the plain, watered by copious showers; vegetation springs up from seeds sown by the winds; and, behold! a landscape that delights the eye of every observer and inspires the brush of the painter and the pen of the poet as no haphazard production could delight or inspire.

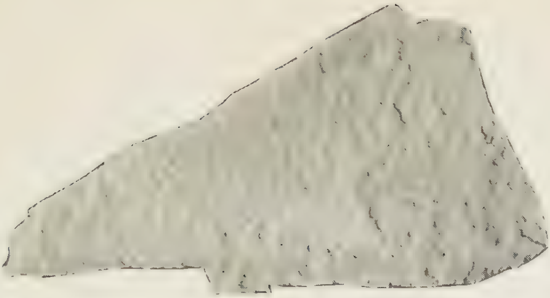

FIG. 6 — Fossil rainprints, Carboniferous Age.

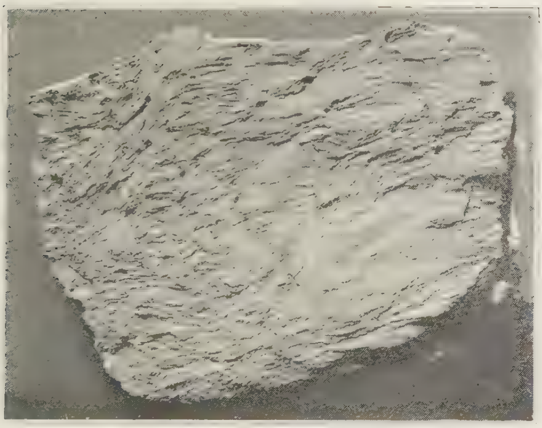

FIG. 7 — Travertine from Jupiter Terrace, Yellowstone Park.

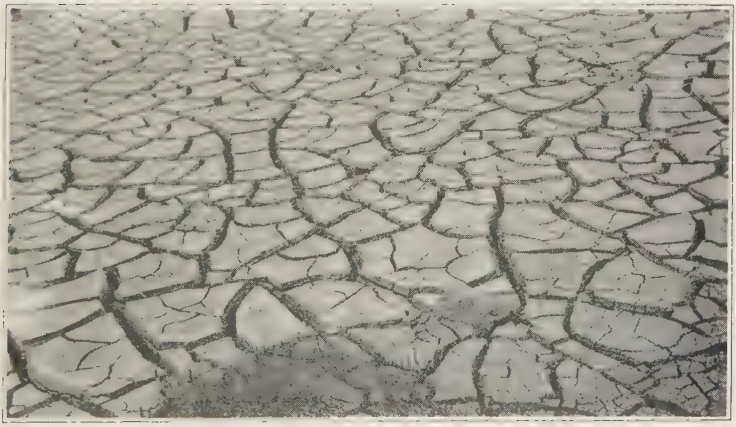

FIG. 8 — Recent "drying cracks," resulting from shrinking of mud in drying after a long wet season.

Geological Formations

"There's beauty all around our paths, if but our watch-
ful eyes
Can trace it midst familiar things, and through their
lowly guise."

Mrs. Hemans.

GEOLOGY is the science of the earth. Among other things, it deals with the structure and composition of the earth, its surface topography and the methods by which it has reached its present condition. Naturally the first inquiry is, whence came the materials of which the earth is composed?

So far as human knowledge goes, matter has always existed in one form or another — has had no beginning and can have no end. That is no violent presumption, nor is it the only possible supposition. If the human mind cannot readily comprehend the possibility of creating something out of nothing, neither can it readily comprehend the existence of anything without beginning and without end.

The original "nebular hypothesis," which assumed that the solar system was evolved from a gaseous nebula, has been generally abandoned because of its failure to conform to physical laws and geological facts. According to the comparatively new "planetesimal hypothesis" the sun, with the earth and other planets, were derived from a spiral nebula, composed not of gases, but of small solid or liquid "bodies, molecules or aggregates moving in orbits about a common center and forming a disk-like system" (Chamberlin and Salisbury).

Throughout the geological ages the superficial layers of the earth's surface have been subject to strains and stresses, resulting in folds and faults, producing surface inequalities, upon which erosion, Nature's great sculptor, could begin its work. Through the action of running water, chemical solution and other agencies, the process of tearing down rock masses and building new formations from the more or less pulverized materials began when the first wrinkle appeared in the earth's crust and the first rains fell upon it, and will continue as long as water continues to fall upon unequal surfaces. Materials have been thus used over and over, transported from place to place, throughout the ages, new formations ever building from the old, with a constant procession of ever-changing landscapes.

In the sedimentary formations that constitute nine-tenths of the earth's exposed land area, we have a record of changing conditions of the same character as the changes now known to be going on. These sedimentary formations are composed of sand, gravel, clay and other materials, torn from their original situation at some time or other, recent or remote, transported by water, wind or ice, and redeposited, often many miles away. Thus the rocks of the Alleghanies and the Rockies, fifteen hundred miles apart, slowly ground to mud and fine sand by the forces of destruction always at work, transported down the long rivers, finally mingle on the Mississippi delta, contributing their share toward the building up of a new formation there, upon which will be constructed new landscapes in ages to come.

Each change in the chemical or physical character of the sediments is a record of a change in the conditions under which deposition proceeded; so the successive layers of rock may be considered leaves of one of Nature's books. Stratification is due to the sorting power of the transporting medium. The power of water to carry sediment in suspension is governed largely by its velocity, which in turn depends upon its volume, the depth and grade of the channel and other factors. As the current of the stream varies from low water to flood level, the quantity of material it carries and the kind and size of the particles vary. As the streams deepen their valleys, they cut successively into different formations. Hence from time to time the kind of material they pick up and transport varies. Consequently, as the sediments are deposited, layer by layer, they establish a record of the controlling conditions, which in many cases may be read by the geologist and correctly interpreted.

An underloaded stream may deepen its channel, because it can pick up more material along the way, while an overloaded stream will deposit part of its load and thus build up and perhaps ultimately fill its valley. This is beautifully shown by a photograph of the record left by a recent summer storm (Fig. 13). The first rush of water from the dry hillsides washed great quantities of sand and mud down into the narrow channel of a tiny rivulet, overloading the stream, which proceeded to fill its channel and spread the remainder of the debris out over its flood plain. The rain became more gentle, the stream became less heavily loaded and began to re-excavate its channel. The rain ceased, still further lessening the load, the cutting of the channel was accelerated. The stream became almost clear and soon the work of re-establishing its channel was complete, leaving a series of terraces to mark the successive stages in the process.

A sluggish current transports only light or finely-divided material. The resulting formation is very fine-grained and often in layers scarcely thicker than the leaves of this book (Fig. 12). By currents of greater velocity grains of sand may be transported, sometimes forming great beds of massive sandstones (Fig. 32). A swift stream may transport coarse gravel (Fig. 14), while a tumultuous torrent may transport boulders up to several feet in diameter (Figs. 15, 16), partly by undermining and rolling them along the bed of the stream. Even storm waters on a dry hillside may move giant boulders down the slopes by undermining them (Fig. 17), thus producing marked transformations in the landscape.

These deposits of various kinds, accumulating to a thickness of hundreds or thousands of feet, are then subjected for ages to the action of percolating water, pressure and perhaps some heat, until they become thoroughly cemented together and form solid rock. A bank of unconsolidated mud, sand, gravel or boulders (Figs. 13, 14, 15, 29) and a ledge of hard rock (Figs. 16, 27, 32) merely represent different stages of rock-making.

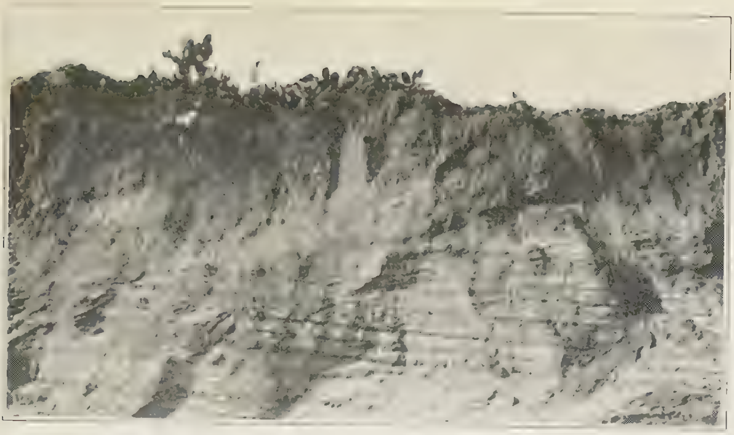

Fig. 12 — Thin-bedded Pleistocene sandstone, crossbedded, wrinkled by lateral compression.

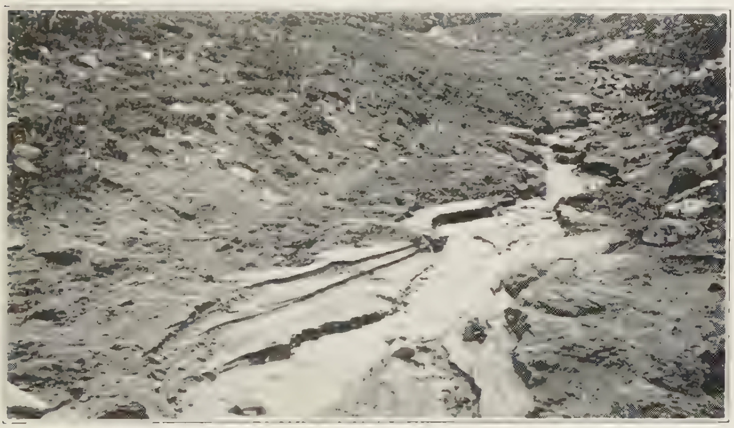

Fig. 13 — Record of a recent storm in a tiny rivulet.

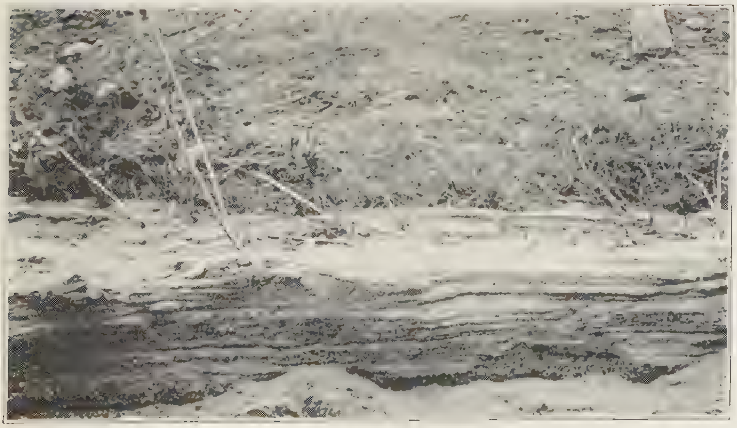

Fig. 14 — Recently-deposited unconsolidated gravel, exposed by more recent erosion, in the channel of an intermittent stream.

Geologically, such deposits are rock, whether consolidated or not.

Where the waters of ponds, lakes or the ocean are nearly free from mud, sand and gravel, limestones may form, composed chiefly of shells. They may be ground up by the waves so as to form very fine-grained limestones or may accumulate in more or less broken condition in quiet water beyond the severe action of waves and thus form shell conglomerate. Such is the Coquina stone of Florida. There are also probably purely chemical deposits of limestone. There are calcareous rocks composed chiefly of the tests of foraminifera, siliceous rocks derived from the beautiful microscopic diatoms and coralline rocks built up by tiny polyps.

All of these various kinds of rocks, differing in their physical and chemical characters, consequently varying in the degree of their resistance to erosion, to a very great extent control topography and are consequently important factors in the production and alteration of scenery. Other rocks, usually of more local nature (Fig. 18), especially volcanic rocks (Figs. 47, 77, 94), often enter into the production of landscapes. Granites, on a much more extended scale, dominate some of the grandest scenery of the world (Fig. 1), where they constitute the backbones of great mountain ranges.

Some of the best examples of minor deposits entering directly into the composition of weird and striking landscapes are those of Yellowstone Park. Among the strange things to be seen there, adding to the beauty of the scenery, not the least interesting are the hot spring deposits. Hot waters carrying carbonate of lime reach the surface through the springs or spouting geysers, deposit their lime about the openings and thus build up fantastic travertine terraces, worthy of the high-sounding names bestowed upon them (Fig. 18). The "lime-eating" algae (Fig. 7) greatly facilitate the deposition of the lime of the travertine terraces and the siliceous sinter of Geyser Basin.

A knowledge of the names of formations and the geological ages they represent is not of greatest importance in considering the effects of geological formations upon scenery; but a knowledge of their power of resistance to erosion and disintegration is of paramount importance. Still, in all geographical and geological discussions and investigations it is very convenient to be sufficiently familiar with formations to recognize them and call them by name, and it is certainly a source of delight to be able to distinguish them and to determine their age as one travels about the earth. Furthermore, knowing the formations makes it possible to more readily analyze and comprehend the scenery, as a formation is likely to retain the same characters and consequently to produce the same effect upon landscape over large areas.

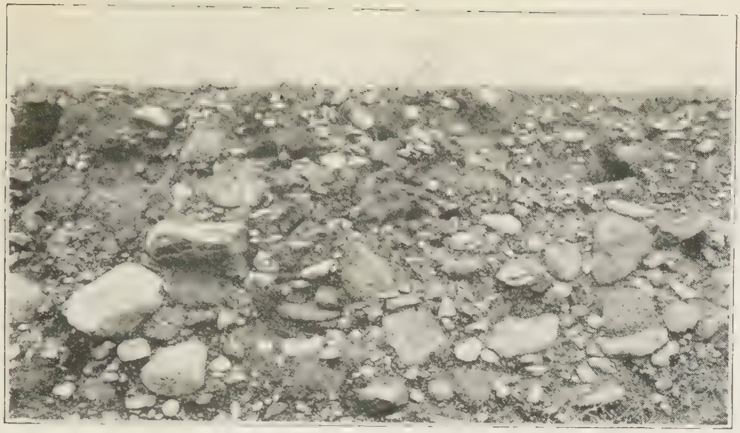

Fig. 15 — Unconsolidated Pleistocene conglomerate deposited by a stream which has since cut its channel 100 feet deeper, leaving the boulders and gravel on a terrace.

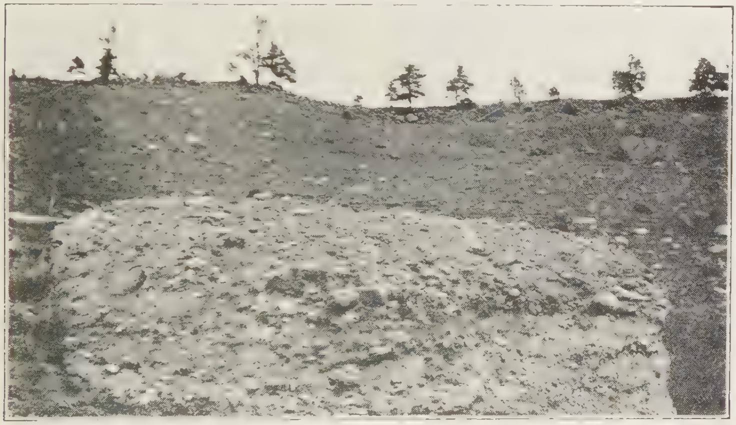

Fig. 16 — Hard Carboniferous conglomerate, weathered out in a large block, transported a mile by storm-water undermining, and redeposited with coarse material forming a new conglomerate not yet consolidated.

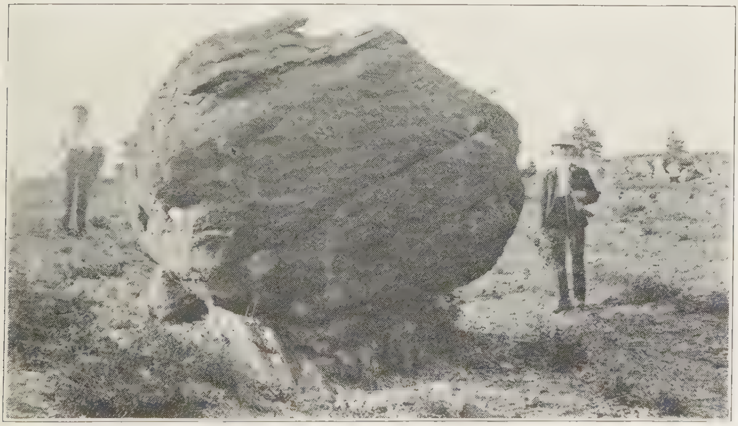

Fig. 17 — Boulder being transported down a steep slope by storm-water erosion undermining it.

The Rise and Fall of Continents

"Nature ever yields reward
To him who seeks and loves her best."
BARRY CORNWALL.

FOR all practical purposes we may consider the continent upon which we live a stable and permanent affair. The storm-tossed passenger who for days has felt the pitching and rolling of the vessel as it rose and fell with the heavy seas rejoices when he again plants his foot upon what he is pleased to call "solid land." It is solid compared with the sea upon which he has been tossed, but when the earthquake shakes the land and demolishes massive buildings he begins to wonder just how solid the continent may be.

Though relatively stable as compared with many other things, continents have always been subject to constant changes in their relation to sea level. Not only has our own continent been repeatedly elevated and depressed, as a whole or in part, during the earlier stages of its history, but there is plenty of evidence of important changes within very recent times, and every reason to believe that such oscillations are in progress at the present moment. Old beaches in various parts of the world, found far above sea level, contain shells of the same species as those now living in the ocean not far away, speaking eloquently of the recency of their elevation.

Certain coasts have been submerged and re-elevated within historic time. Ancient buildings once standing upon the land are now submerged by coastal subsidence.

Continents do not drop off abruptly into the deep sea. Their off-coast regions are occupied by considerable areas of shallow water. Shallow portions of the ocean far from the shore-lines are in some cases known to mark the positions of the former coastal plains. A movement of a few hundred feet upward may expose to view thousands of square miles of territory now beneath the tide. A slight submergence may convert large areas of low land into shallow seas. The scenic effect of such conversions may be imagined. So slow are such changes in level that usually they may be detected only by very accurate measurements and the lapse of a long time between measurements. Variation in the rate of movement at different points along a coast sometimes leaves its record in the fact that continuous ancient beaches are found at a greater elevation above the sea at one point than at another.

Not always are the movements of the earth's crust gentle. Though the slow, constant, widespread movements are far the most important geologically, sometimes great areas are elevated or depressed in a few hours or a few days, with profound immediate influence upon the local scenery. It is said that at the time of the great South American earthquake of 1835, affecting an area of six hundred thousand square miles, the coasts of Chili and Patagonia were elevated from two to ten feet. Thirteen years earlier the same coasts are said to have been elevated from two to four feet during another earthquake. In Alaska the earthquake of 1899 was accompanied by sudden elevation of portions of the coast, with a maximum movement of forty-seven feet. In 1911 and 1912 severe earthquakes in the Mississippi Valley were accompanied by subsidence of several feet in large tracts of land, converting them into swamps and lakes, portions of which retain the name "the sunk country" in memory of the event. A few years later an earthquake in India was accompanied by the subsidence of hundreds of square miles of territory, which was converted into a lake, while a small tract was elevated ten feet. The name given to the elevation, "The Mound of God," serves to keep the incident fresh in the minds of the inhabitants.

If these sudden and violent exhibitions of Nature's forces can produce such scenic effects, how much greater must be the effect of greater forces acting for long periods over much larger areas. Ocean tides have ebbed and flowed where now the Rocky Mountains push their summits to altitudes of more than 14,000 feet above sea level. Marine fossils are found in the rocks 10,000 feet above sea level. A subsidence of 500 feet would flood St. Louis with salt water, 1,000 feet would drop St. Paul beneath the tide, while 5,000 feet would again bring oceanic waters to the base of the Rockies. What assurance have we that at some time in the distant future the Rocky Mountains may not again bathe their feet in the waters of the Atlantic and the Great Plains be again transformed into an ocean's bed?

In considering these stupendous continental oscillations so imperceptibly going on through the ages, we are led to recall LeConte's declaration that earthquakes and volcanoes are "but occasional accidents in the slow march of these grander movements."

Since changes in level affect the coast lines, the rate of erosion and deposition of sediments, the climate, and consequently the vegetation, their effect upon landscape is tremendous. From a knowledge of some of the facts and principles involved, the worshipper at the shrine of Nature may stand upon a mountain overlooking an arid plain once covered by the ocean, and without drawing too freely upon his imagination mentally reconstruct in its larger outlines the now obliterated scenery of the past, while determining the causes of present-day landscapes.

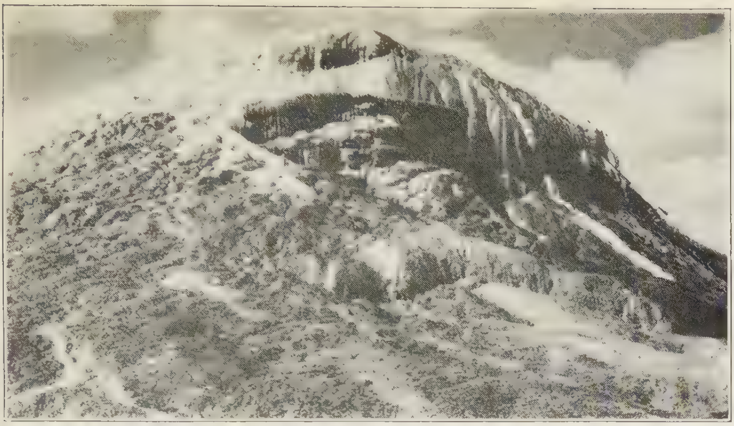

Fig. 18 — A Travertine terrace, Yellowstone Park, composed of lime brought to the surface by hot springs and deposited about algae as the water evaporated.

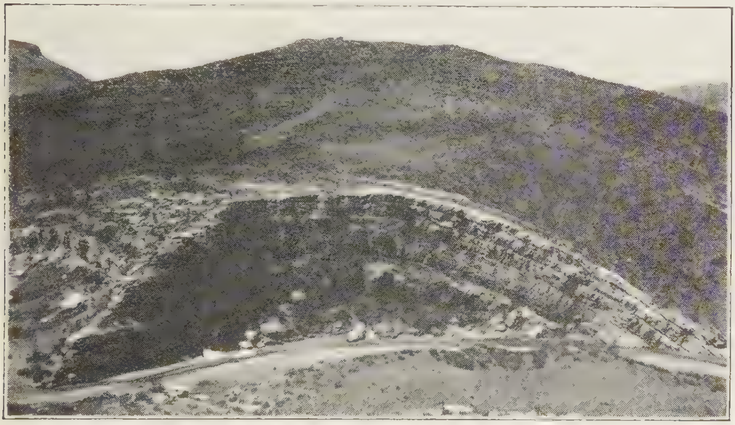

Fig. 19 — Anticlinal fold in Carboniferous strata.

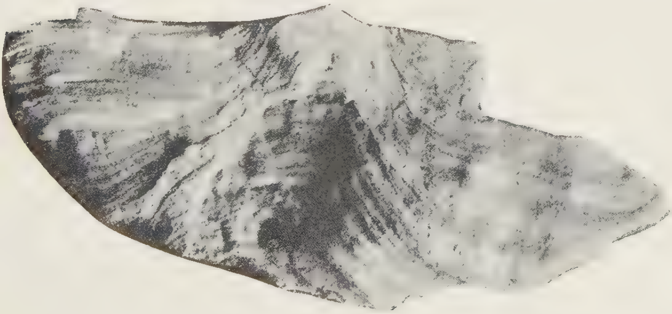

Fig. 20 — Fold in a small hand specimen, Carboniferous Age.

Folds, Faults and Jointed Structure

> "And this, our life, exempt from public haunt,
> Finds tongues in trees, books in running brooks,
> Sermons in stones, and good in everything."
>
> SHAKESPEARE.

TOPOGRAPHIC features of the earth's surface are constant reminders of a battle of the giants — a struggle between titanic forces that began in the remote past, when surface inequalities first became subject to the flow of water and to atmospheric influences, and has continued throughout the ages to the present day. One set of forces is eternally engaged in elevating some portions of the earth's surface above other portions. Another set is engaged in demolishing the elevations and reducing the surface to a common level.

With few exceptions, land-forms such as hills, valleys, mountains, canyons, plains, lakes, rivers and headlands are the result of folds, faults and erosion. The chief agency of erosion is moving water. Atmospheric disintegration of exposed rocks may progress only to a slight depth without the action of wind or water to carry away the debris and expose fresh surfaces. Wind is a powerful agent of erosion under favorable circumstances, but its chief work as sculptor is in modifying inequalities produced by aqueous erosion and in removing debris loosened from the rocks by frost and other agencies.

Before the ocean's waves can begin their work of sculpturing land forms, there must be land raised above sea level upon which to begin their attack. Before streams can begin the carving of canyons there must be surface inequalities of dry land upon whose slopes water may flow with sufficient velocity to cut into the soil or rock and bear away the debris. If the earth's crust were perfectly smooth the water that now occupies oceanic abysses would cover the whole surface of the globe to a depth of about two miles and make erosion on a large scale impossible. It is exceedingly doubtful whether that condition has ever actually existed. It is much more probable that as soon as the earth became a globe with a solid crust bearing water on its surface and surrounded by an atmosphere, the surface began to wrinkle from various causes and to develop lines of weakness along which further folding would naturally proceed. However that may be, at some stage in the earth's history inequalities came into existence and became exposed to atmospheric influences and stream erosion which have never since ceased their work.

Manifestly such inequalities would be the inevitable result of just such folds and faults as we find in the rocks in all parts of the world (Figs. 19, 20, 21, 22, 23). The crumpling of the earth's crust, begun so long ago, still continues. The ease with which rocks yield to pressure depends upon their chemical composition, physical characters, conditions of pressure and the plasticity resulting from heat and percolating water. The more plastic layers may bend without the slightest fracture. Other

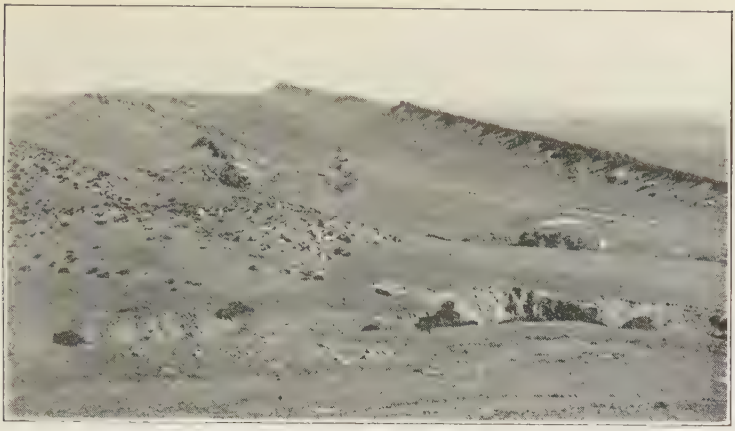

Fig. 21 — Monoclinal fold in Cretaceous sandstone tilted to a high angle by the mountain uplift, then dissected by differential erosion of hard and soft strata.

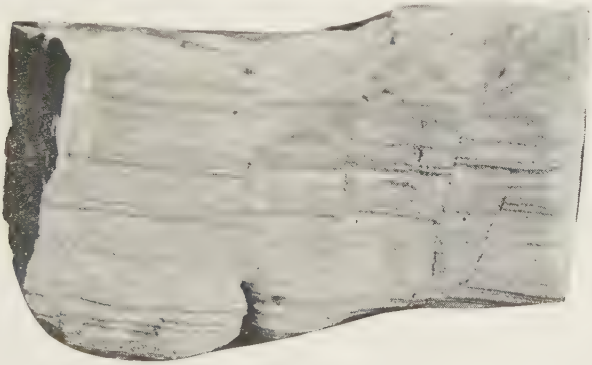

Fig. 22 — Distributed fault in a small hand specimen, Carboniferous Age.

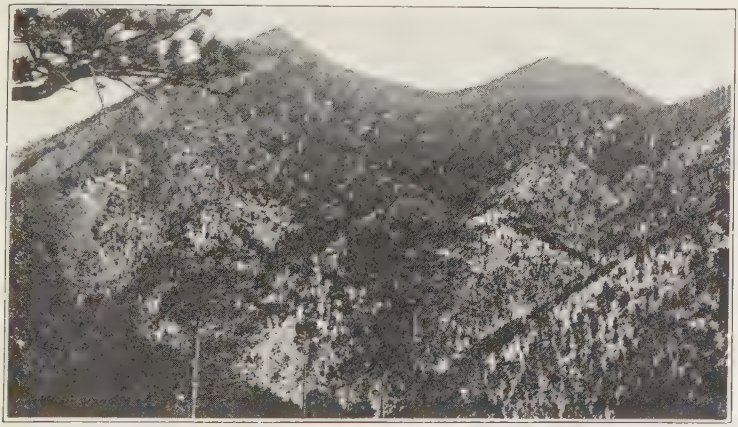

Fig. 23 — South Boulder Peak from the northwest—"twinned by a fault." The tilted strata have been broken by a fault and the portion once at the base of the slope has been pushed up to about the same altitude as the once-higher point.

layers in close proximity may simply shorten without bending or breaking. Other layers may be crushed into fragments and afterwards, by action of water and pressure, be cemented into solid breccia.

A proper amount of force exerted for a sufficient length of time will cause almost any material to bend without breaking. This quality is found in iron, lead, hickory and other materials in varying degree. That a degree of heat sufficient to make the material more plastic without fusing greatly aids in bending them is well known in case of glass, iron and many other substances. The same is true of rocks. It is quite clear that the amount of time and force necessary to produce large folds in the rocks is very great, but not greater than we can afford to allow, in the light of modern geological knowledge. Carefully conducted experiments show that rocks may be deformed by pressure and that the various kinds of folds, faults and cleavage found in the rocks may be produced artificially in more plastic materials in a short time.

All sedimentary rocks were originally deposited in a nearly horizontal position (Fig. 14), but now may be found tilted to almost every conceivable angle (Figs. 21, 32, 92), some strata being vertical, some even overturned. Folds may exist so minute that several would be included in a small hand specimen (Figs. 12, 20), or so large as to embrace whole counties (Fig. 19). In the Appalachian Mountains some folds are known to involve 40,000 feet of strata, single flexures reaching a length of one hundred miles and a width of twenty miles. A fold in the form of an arch is an anticline (Figs. 19, 20), a trough is a syncline (Fig. 24), while in a monocline (Fig. 21) the strata simply dip in one direction.

If folds were all simple undulations unaffected by any other phenomena or processes, it would be comparatively easy to ascertain the geological structure of any region and the work of the petroleum geologist in the search for "oil structures" would be much simplified. All hills would then be anticlines and all valleys would be synclines. In the field one is too often confronted by exactly the opposite condition, as a result of erosion, anticlines occupying the valleys and synclines forming the hills (Fig. 24). The reason one plainly may see. Erosion attacks the anticline, because it is an elevation down whose slope water may flow with sufficient rapidity to cut into the rock. It soons forms a channel down the slope. The stream, having entrenched itself, continues to flow in the same channel, cutting it constantly deeper and laterally

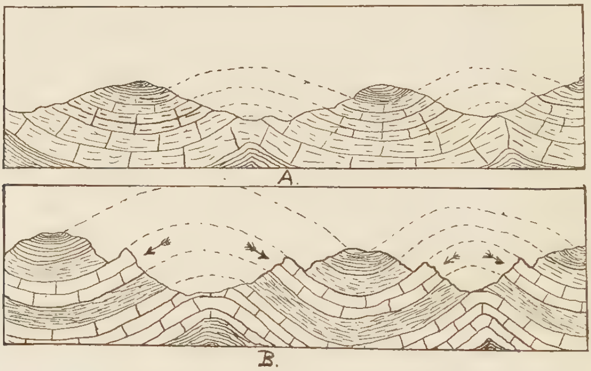

Fig. 24 — Diagram showing cross section of eroded folds. *A* shows how erosion of apex of anticline may make a valley, leaving the syncline standing out as a hill. *B* shows effect of harder strata in producing minor hills, indicated by arrows.

widening it, thus making a valley of the anticline. Meanwhile the same thing occurs on the next anticline, so that eventually the syncline is left as a hill or divide separating the two valleys. Then the syncline being now the high ground and hence subject to rapid erosion, a fresh attack is begun upon it that in time may reduce the syncline again to a valley or to the common level of the surrounding region.

To make the structural problems more intricate, we have also to deal with a great variety of faults or breaks of all sizes in the rocks. Some are almost microscopic, others of a size permitting several in a small hand specimen (Fig. 22), while in others the displacement may be hundreds or thousands of feet (Fig. 23). When a fault occurs, usually the rocks on one side of the break are forced above or below the level of the corresponding strata on the other side. In South Boulder Peak, Colorado, where the break occurred in steeply upturned strata, the lower part was pushed up to a level with the upper part, making a twin peak (Fig. 23). It is not uncommon to find a series of minor faults lying close together, which phenomena is called a distributed fault (Fig. 22).

A fault may develop slowly, or it may come swiftly, with destruction of life and property. A fault developing suddenly, or a fresh slip along an old fault line, results in an earthquake. The Inyo earthquake of 1872 was accompanied by a slip of twenty-five feet, forty miles in length. In the Sonoran earthquake of 1887 the fissure was one hundred miles in length, with a vertical displacement of eight feet. In Japan as recently as 1891 a great earthquake formed or reopened a fault seventy miles long, with a displacement of twenty feet. The fault involved in the great San Francisco earthquake is well known and has been studied. Thus we see that geological processes popularly supposed to be things of the past are still in active and not infrequent operation. When we consider that slips along the same fault line may occur at intervals for many centuries and may in the end reach a total displacement of hundreds or thousands of feet, as some are known to have done in the past, we may realize what a tremendous influence they may have upon scenery in some portions of the world.

Stratification is characteristic of sedimentary rocks, but jointed structure is common to all rocks (Figs. 2, 25, 26, 35, 94). Such joints may be more or less directly connected with folding or faulting, or due to the same causes — tension and compression resulting from crustal movements. In lavas jointed structure seems to be developed in cooling, producing cubes and rectangular columns of great importance in the make-up of striking scenery (Fig. 94), as in the Devil's Tower of Wyoming and the far-famed Giant's Causeway of Ireland. The action of frost in breaking up the rocks is partly controlled by joint structure (Fig. 25). The effect of joint structure is well shown by the cliffs of the Dolores Canyon in Colorado (Figs. 2, 26). Therefore such structure has a very important bearing upon scenery, indirectly in facilitating the disintegration of rocks, and directly in determining the forms they assume as they are sculptured by

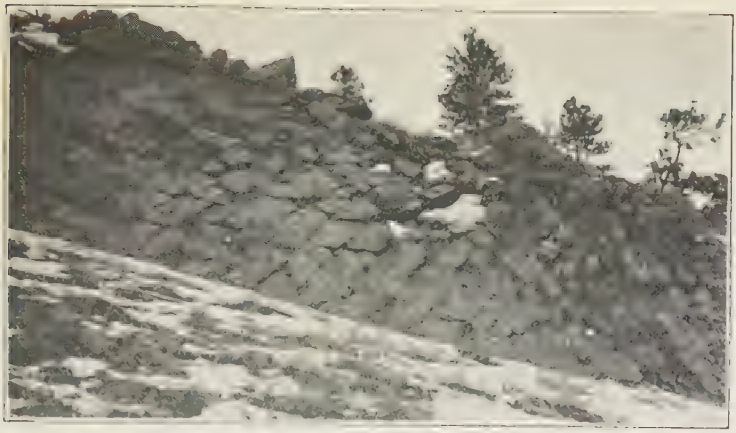

Fig. 25 — Joints in Cretaceous sandstone, widened by the expansive power of freezing water.

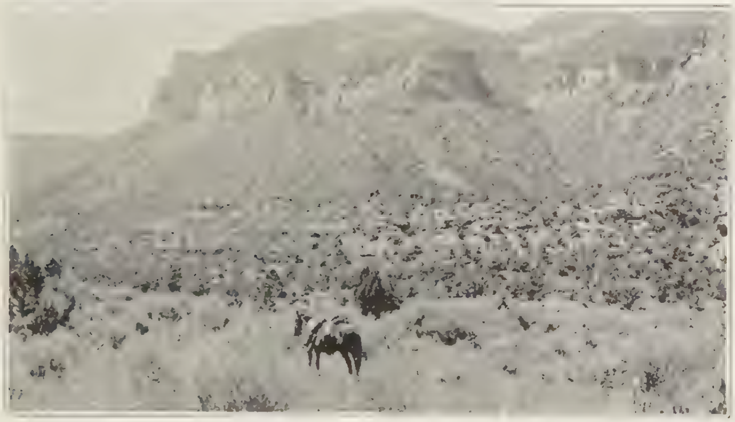

Fig. 26 — Triassic sandstone, showing the control of erosion by vertical jointed structure.

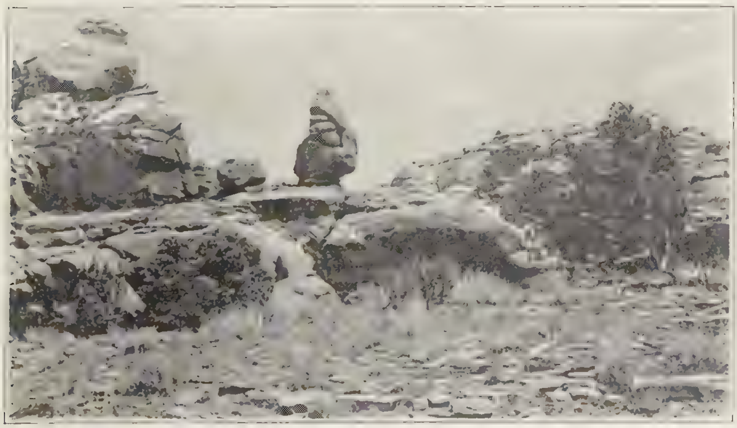

Fig. 27 — Statue carved in massive Jurassic strata by wind and storm-water.

atmospheric and aqueous agencies, besides being itself an interesting feature of the landscape in many cases.

Were it not for the various agencies ever engaged in the production of folds, faults and related phenomena, the varied scenery of today would be impossible, but all would be a monotonous expanse of land and sea, in which the development of life could not have reached so high a plane as it has under these varied conditions.

Erosion and Transportation

> "He is the greatest artist, then,
> Whether of pencil or of pen,
> Who follows Nature."
>
> LONGFELLOW.

EROSION is the combined chisel and giant plane by which Nature, speaking somewhat metaphorically and anthropomorphically, seeks to plane off all inequalities and reduce the surface of the earth to a common level. Not a hill but has been wholly or partly fashioned by erosion; not a valley but is due partly to its handiwork; not a plain but is witness to its operations! Wherever a difference in altitude occurs chiselling begins. If the slopes on all sides of each elevation were exactly equal and composed of materials in exactly the same chemical and physical condition, and if precipitation and temperature were exactly equal on all sides, then storm waters would flow off in an even sheet and erosion would be uniform. There would be no rivers, no canyons, no rugged peaks. Such conditions, however, do not occur in Nature. Slopes differ in their angle of divergence from the horizontal. Upon the steeper slopes the flow of water is swifter, consequently erosion proceeds more rapidly, other factors being equal. Rocks differ in chemical composition, hardness and other resisting qualities. Hence some portions of the slope will give way more rapidly

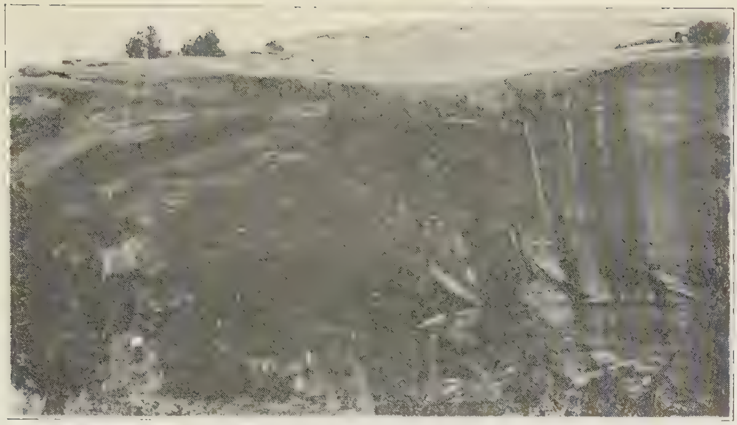

FIG. 28 — Cavern in Jurassic sandstone, excavated by action of wind and percolating water, formerly occupied by prehistoric inhabitants.

FIG. 29 — Sand dunes, showing protective sand-binding vegetation.

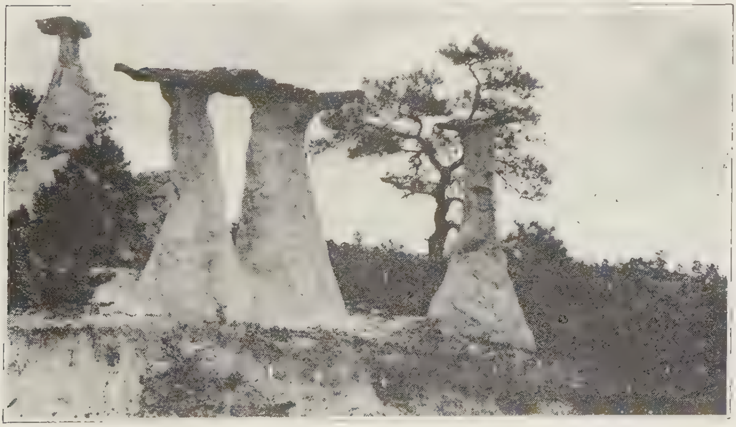

FIG. 30 — Pedestal rocks in Monument Park, Colorado, resulting from aeolian and storm-water erosion of soft rock protected by hard cap-rock.

than other portions, producing slight channels, perhaps indiscernible to the eye, but sufficiently pronounced for the water, so susceptible to slight differences, to follow. These channels, extending their reach and gathering more and more water, are the cause of their own increase. If the process is not interrupted by renewed down-cutting, they widen their valleys until they destroy the divides between and blend all into a great plain.

Running water is Nature's great transportation system, compared with which the combined railway systems of the whole world sink into insignificance. The perennial streams transport enough material each year to cover immense areas with deposits of fine silt, which in the aggregate weigh many thousands of tons. The flood plain of the Nile over which it distributes its load is all Egypt, comprising 30,000 square miles. The Mississippi flood plain perhaps covers an equal area. These and hundreds of other streams, great and small, upon all the continents and larger islands, year after year, century after century, in flood and low water, proceed with the tremendous task imposed upon them by the laws of Nature, of grinding away plateaus, hills and mountains and transporting them piecemeal to the sea. The journey is usually not made by continuous passage, but by easy stages. Materials are picked up and carried forward for a distance, then deposited where they may rest for hours, days or centuries, when they are again seized and carried farther upon their involuntary journey.

Perennial streams are not alone in this work. They are fed by storm waters over wide areas outside the channels of the ever-flowing streams. With every passing shower soil is loosened from the hillsides, and temporary rivulets, bearing their loads of mud and sand, rush to join the brimming rivers. Ocean currents, too, are ever at work, cutting out and bearing away sediments, carrying them alongshore or out to sea in the construction of new formations.

Then, too, Nature runs several independent transportation lines and erosive agencies of importance. Though the dust that flies with every summer breeze may cover the foliage and mar the scenery of today, it may be making the landscapes of the future. One little flurry of wind or cloud of dust can have but little effect, but countless repetitions through the centuries build thick deposits that must be reckoned with as important geological phenomena, and in some instances are almost entirely responsible for scenic effects. The sands of Sahara encroaching upon the valley of the Nile, the blown sands building dunes (Fig. 29) along our own coasts and in San Luis Valley and North Park, Colorado, impress even the casual observer with the effect of wind upon the landscape. Doubtless in the aggregate the indiscernible work of the wind throughout the world far exceeds the more noticeable work in extreme cases.

At certain points along the Columbia River, where, in the absence of vegetation, the bare, loose sand lies directly exposed to the action of the atmosphere, it is not uncommon to see a thin film drifting over the surface before the wind so as to appear as if the whole body of sand were flowing past like a mighty river. In portions

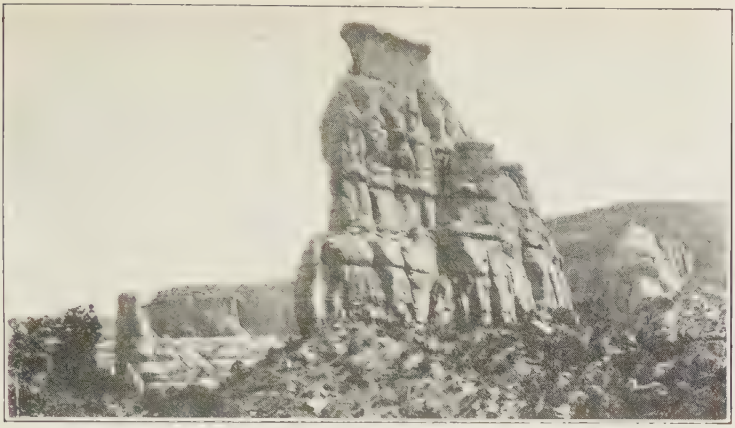

Fig. 31 — Erosional pinnacles in Colorado National Monument.

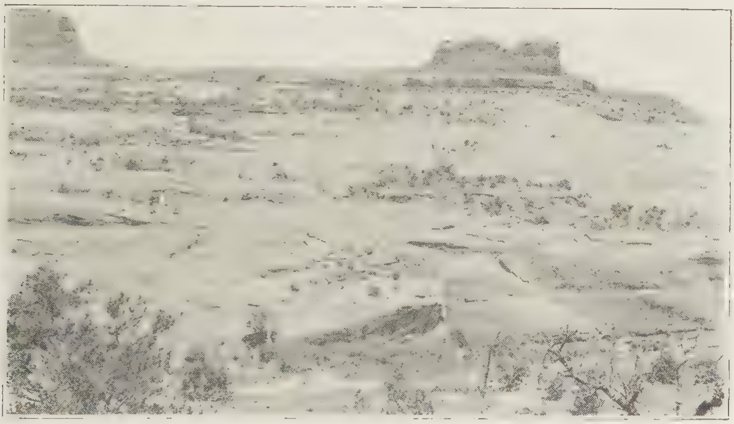

Fig. 32 — Characteristic weathering of massive horizontal sandstone in an arid region devoid of heavy vegetative cover.

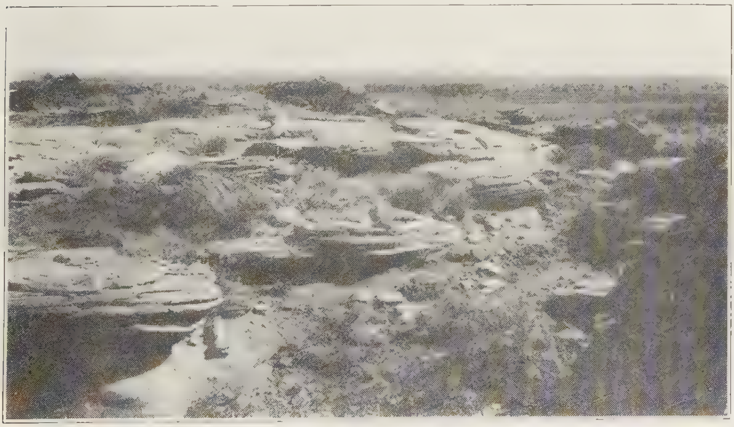

Fig. 33 — Differential erosion in horizontal concretionary strata.

of the semi-arid West, where the wind for ages has been engaged in carving the sandstone into fantastic buttes and building an inextricable confusion of sandhills, the fine sand drifting past at times gives one the impression that the buttes themselves are in motion. The grotesque monuments and statues (Figs. 27, 30, 31), sculptured from massive sandstones partly by the wind assisted by storm waters and other agencies, are a source of great interest to the traveller. Sand-bearing winds, sweeping across rock surfaces or playing hide-and-seek among crags and peaks, act as sand blasts, scouring and grinding, resulting in odd cavities (Fig. 28) and fantastic forms unlike those produced by rains, frost and running water. As in aerial erosion, so in aqueous erosion, it is the sand borne by the water that carves deep canyons into hard rock, a thing clear water alone could not very effectively do.

The ocean's waves, eternally pounding at the sea cliffs, picking up sand and gravel and dashing them with great force against the rocks alongshore, are at work guttering, carving, planing, scraping, shaping the shore contours and rock forms, producing scenery quite unlike that resulting from flowing water, wind or ice. The inroads of the ocean upon exposed coasts (Figs. 42, 43, 68, 69) during its angry moods are more spectacular; but not less important are the results of the steady lapping of the surf in its quieter periods, continued year in and year out, chiselling away the rocks little by little, but always chiselling.

Moving ice is another important agency of erosion and transportation. During the glacial epoch the ice of the great continental glacier carried enormous quantities of material long distances and spread it out as a thick blanket over large portions of the upper Mississippi Valley. This gives to the glaciated region characteristic scenery and topography, easily distinguishable from those resulting entirely from the action of running water. The hummocks, the small lakes, the erratic boulders, the moraines, plainly tell the story of their origin. During the same period, in the higher mountains of the West, local glaciers transformed V-shaped valleys (Fig. 74) into U-shaped valleys (Fig. 75), shaped, striated and polished *roches moutonnées*, or "sheep rocks" (Fig. 66), constructed thousands of rock-basin and morainal lakes (Figs. 64, 65, 66, 67), and left in some localities bewildering networks of moraines (Figs. 65, 73) composed of sand, gravel and boulders (Fig. 76) borne by ice-streams (Fig. 72) from neighboring mountain peaks.

Besides bearing, pushing and dragging materials in perennial streams and intermittent storm rivulets, and carrying them in the air, wind and water effect transportation by undermining boulders, large and small, resting upon sloping ground (Fig. 17). After every storm the water, gathering in small rivulets, rushes down the slope, cutting the soft soil or shale away from beneath the rocks, allowing them to gradually creep downward, or perhaps to roll suddenly forward as their support is removed. Water is greatly assisted by wind in the undermining process. Such boulders in transit give to many an otherwise

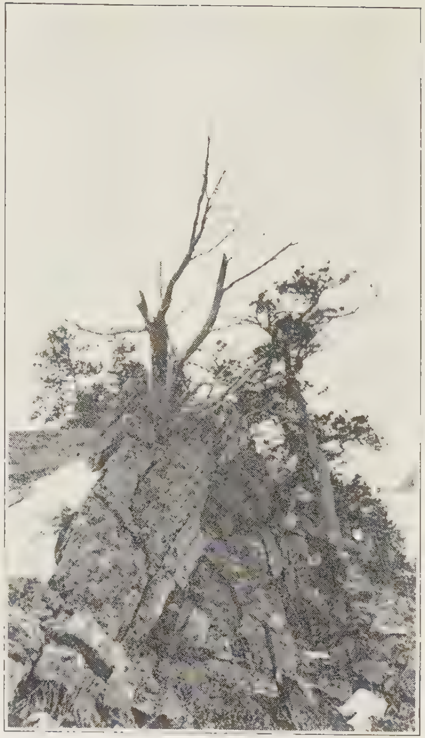

FIG. 34 — Rock cracked by expansion of growing tree roots aided by frost.

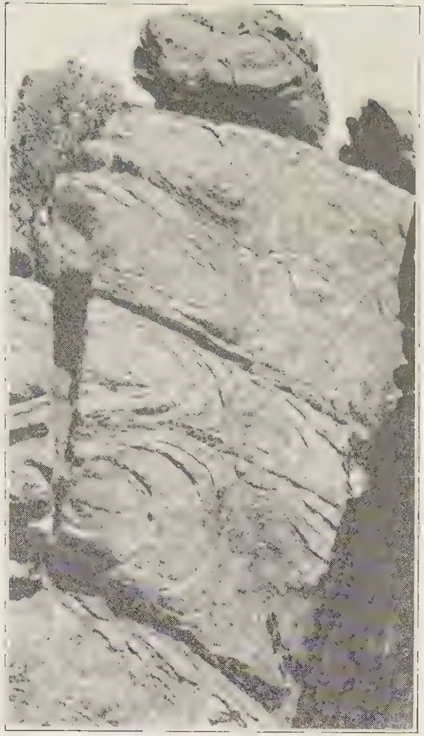

FIG. 35 — Granite scaling concentrically from diurnal expansion and contraction where days are warm and nights cold, aided by frost. Also shows a joint widened by expansion of freezing water.

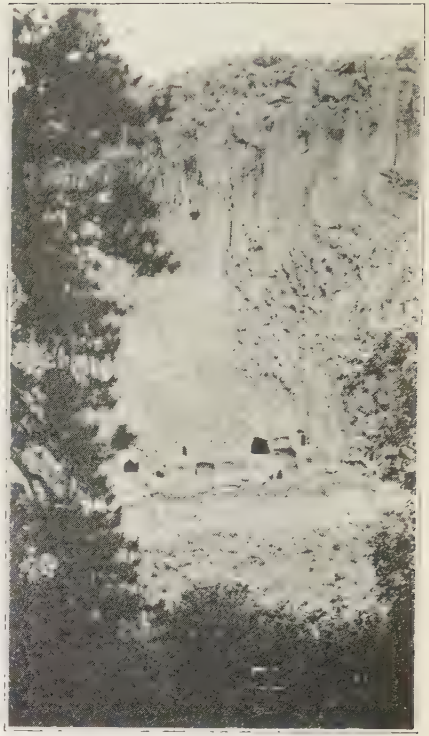

FIG. 36 — Tufa cliff in New Mexico. Caves excavated at base of cliff were back rooms of prehistoric buildings whose walls have crumbled.

barren slope a pleasing relief, and are often mistaken by the uninitiated for poised glacial boulders. The creeping of soils on steep slopes under the direct influence of gravity, unaided by wind or water, is almost universal, and is especially rapid in regions where there is but little protection afforded by vegetation. The creep is materially hastened by expansion and contraction due to alternate freezing and thawing, and to diurnal and seasonal changes in temperature. The creep may proceed so slowly as to be scarcely measurable, or its progress may be varied by an occasional landslide as destructive as avalanches of snow and ice that frequently carry men to death and property to destruction in the fastnesses of the Alps and the Rockies.

Intimately connected with erosion and transportation is the decay of rock masses in place, through physical and chemical processes. This decay furnishes material easily torn apart and transported by wind and water for the filling of depressions and the construction of new formations. Disintegration depends not more upon the hardness of the rock than upon its chemical composition and physical condition. Soluble constituents of granite, yielding readily to atmospheric and aqueous influences, render it less durable than some indurated sandstones consisting only of materials almost insoluble; yet granite is popularly supposed to be the most durable of all rocks. Rock of such physical character that water readily percolates it and freezes, is much more easily disintegrated than rock of fine texture not subjected to the expansion and contraction of freezing and thawing. Rocks are sometimes decomposed to considerable depths *in situ,* but where erosion proceeds rapidly, especially in arid regions with slight growth of protective vegetation, the debris may be picked up by streams and storm waters and carried away as it forms, leaving the rocks barren and desolate (Figs. 32, 40). The expansive power of water freezing in the joints and crevices and between strata helps to rend them asunder (Figs. 25, 35). Roots of trees and shrubs growing and expanding in the crevices aid greatly in tearing the rocks to pieces and preparing them for transportation (Fig. 34). The alternate superficial expansion and contraction of the rocks from seasonal and daily changes in temperature, especially in regions where the days are warm and the nights are cold, cause them to scale and crack (Fig. 35), thereby continually exposing fresh surfaces upon which the disintegrating forces may act. All these and other processes reducing the fragments to smaller dimensions are perpetually at work making soil of the hardest rocks. When we bear in mind how largely vegetation and erosional effects enter into the production of scenery, how dependent vegetation is upon soil conditions, and how dependent erosion is upon the ease with which materials may be dislodged, we may comprehend the importance of decomposition of rocks in the making of a landscape.

The most stupendous mountain systems in the world would be tame and comparatively uninteresting were it not for the phenomena of erosion, which has cut and gashed their rocky flanks, separated their peaks by deep gorges, and torn the summits into sharp pinnacles (Fig.

1). A study of the southern Rocky Mountains has revealed the fact that this vast area constitutes a great plateau, deeply dissected by the streams that bear away the waters from the melting snows, on one side to the Gulf of Mexico, on the other to the Gulf of California. The Grand Canyon of the Colorado, with its intricate system of tributaries, the most remarkable canyon system in the world, could not exist except for erosion, which has cut through solid rock to a depth of much more than a mile. In its place would be a monotonous plateau. The canyons expose in their walls the rocks that relate many of the principal features of the geological history of that portion of the world from the Algonkian through the ages to the Pleistocene. The river and its tributaries are still cutting downward along their narrow lines at the bottom, while subaerial lateral erosion widens the valleys at higher levels. This process will continue until all the surrounding region over thousands of square miles is reduced to base level, unless some mighty unforeseen revolution ends the erosional cycle and begins a cycle of deposition.

The character of the scenery resulting from erosion depends very largely upon the difference in resistance of different strata and the attitude of the strata. Difference in resistance results in differential erosion. Where hard strata, tilted more or less from their original horizontal position, alternate with soft shales, the shales are easily eroded, leaving the more resistant strata projecting as ridges (Figs. 21, 47, 92). The form of such ridges is controlled by the attitude, or dip, of the strata. If the dip be gentle, the hard layer forms a gentle slope in the direction of the dip, while a steeper slope is formed on the other side by the cutting away of the yielding strata. Obviously, with the strata in either a vertical or horizontal position, or with certain massive rocks not alternating with soft strata, quite different topography and scenic effects would be produced (Figs. 2, 32). Thus from the topography alone one may often at a glance determine the general character of the formations and approximately the dip of the strata. Frequently, too, the rocks have concretionary structure. In that event, whether the strata be horizontal or otherwise, the hard concretions exercise a marked influence upon the erosional phenomena, and consequently upon the landscape (Fig. 33).

A very important element in the creation of scenery is the isolation of hills by erosion (Figs. 37, 38, 39, 40, 41), with its closely related phenomenon, the capture of drainage by one channel cutting headward or laterally into another (Fig. 44). Though more readily studied in some regions than in others, these phenomena are almost universal where erosion is in progress on a large scale. In such regions, wherever we turn we may find hills born of the headward progression of drainage channels from one or more directions (Figs. 37, 38). It is perhaps no exaggeration to say that the majority of hills owe their existence directly or indirectly to this process. A watercourse has a tendency to cut toward its source, especially where slopes are steep and run-off consequently rapid, because it is constantly gathering drainage from that direction. If the process be long enough continued, eventually it will cut through the divide into another water-course, thus perhaps isolating a portion of the divide into a hill, and at the same time, if the new channel be better able to

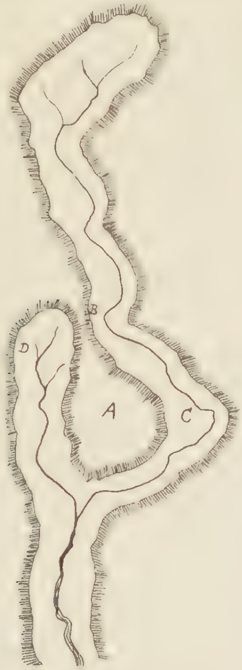

Fig. 37 — Diagram showing isolation of hill, *A*, by headward progression of a tributary, *D*, of the main stream, *C*, which, if continued, would finally cut through the divide, *B*, and result in the capture of the drainage by the tributary.

carry off the water, capturing part of the drainage of the neighboring stream.

In some of the western bluffs of soft, horizontal Tertiary marls, overlaid by resistant sandstone, where erosion is very active, every stage of the process may be seen. The sandstone protects the marls beneath it, allowing winds and rains to eat laterally into the soft material, thus preserving an approximately vertical front —the dominating feature of the landscape. As lateral erosion undermines the cap-rock, portions of it fall away; otherwise it would soon project far beyond the general face of the bluff. Little gullies, starting in the steep wall, eat their way headward into the cliff (Figs. 38, 70). As they progress, laterals branch off. These also work headward until they meet, cutting a hill from the bluff (Fig. 39). Erosion continues to cut the bluff farther and farther back, working it away from the hill, at the same time steadily reducing the size of the hill, but maintaining the steep slopes. Thus hills of various sizes are cut from the main bluffs. (Figs. 38, 39, 40, 41.) More slowly the attack upon the hard cap-rock progresses. As soon as it is gone the destruction of the hill is a matter of only a short time. Remnants may be seen, with their protecting mantle all removed, melting away like a plate of ice-cream beneath the summer sun. By this process some of the most striking scenery of the western plains has been produced. In this way does erosion first sculpture, then plane off and destroy the elevations of land.

Hills may be formed in various other ways. A stream entrenched in a deep valley may slowly cut through the narrow neck of a bend, thus straightening its course, leaving a hill as the result (Fig. 44, at A and G), just as the Mississippi River cuts through the neck of a bend, the abandoned channel of the bend forming a bayou. Or a stream and one of its tributaries may cut

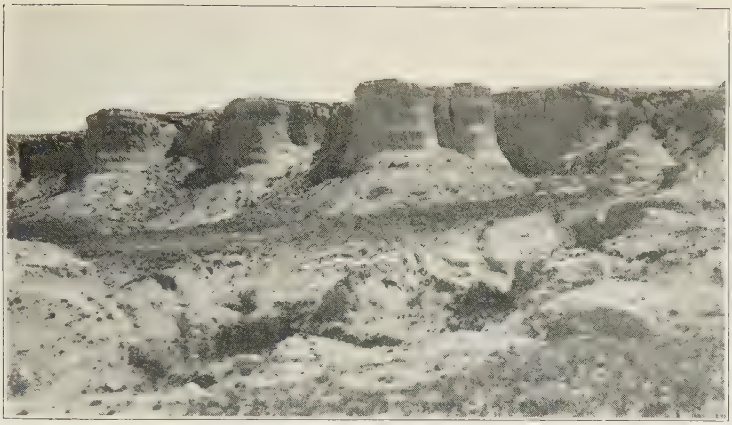

Fig. 38 — Bluff dissected by headward progression in erosion of gullies, the beginning of the isolation of buttes.

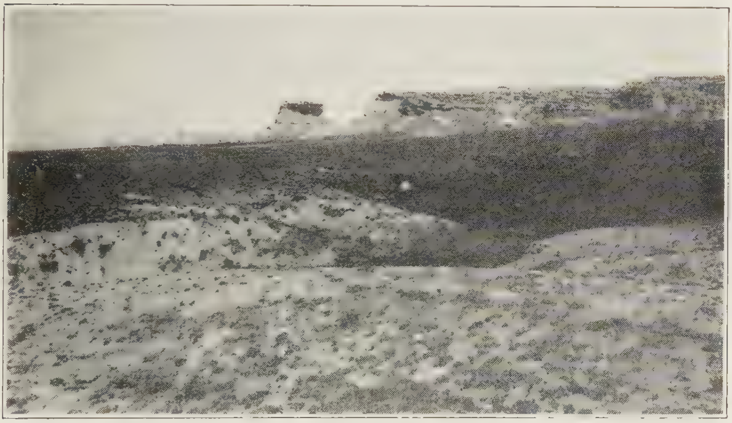

Fig. 39 — A butte isolated from the bluff by erosion.

Fig. 40 — Pawnee Buttes, isolated from the bluffs by more advanced erosion.

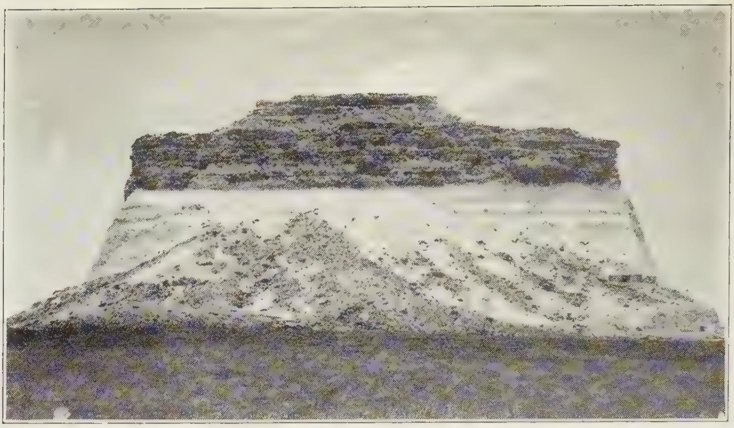

Fig. 41 — West Pawnee Butte, Colorado, showing characteristic topography from erosion of a massive soft formation capped by a hard sandstone.

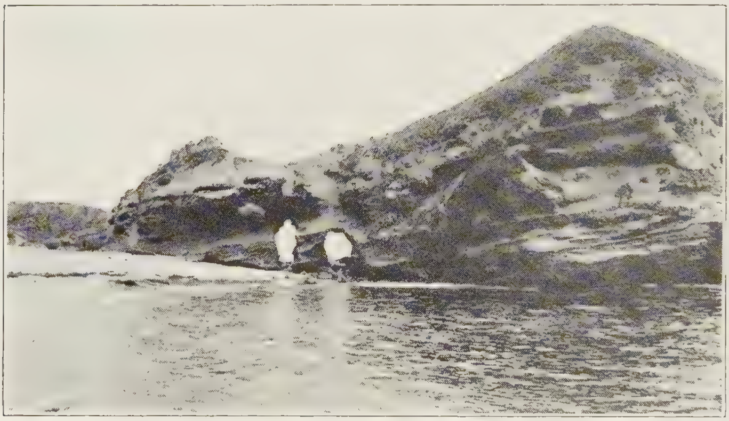

Fig. 42 — Wave-cut arches on seashore, the beginning of the isolation of a hill, which may finally become an island.

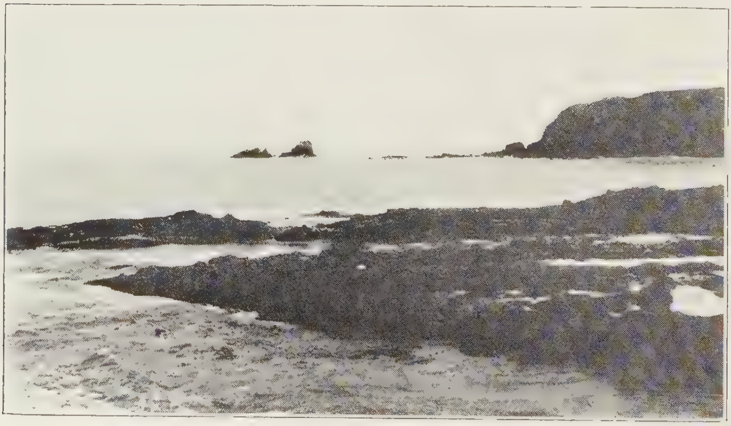

Fig. 43 — An island isolated from the sea-cliff by wave erosion.

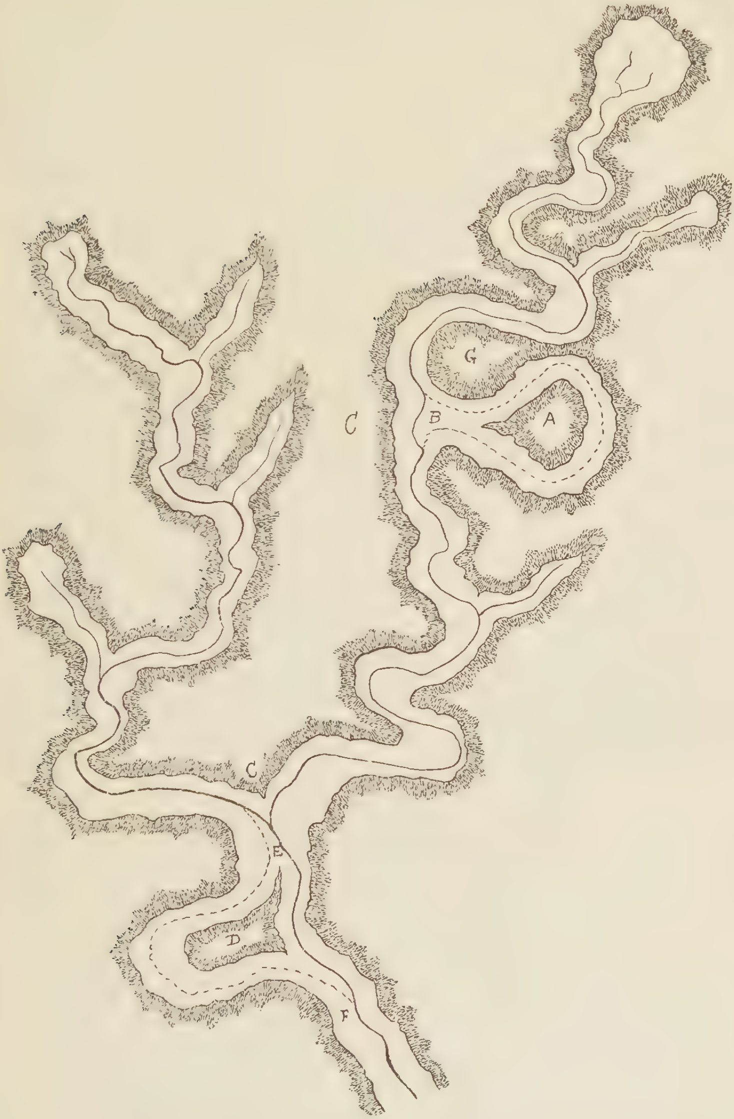

FIG. 44 — Diagram showing isolation of hills by the partial cutting of the neck of a loop in the stream, *G,* by the complete cutting of a neck, *A,* and by a change in the confluence of streams, *D, E, F.*

through their divide, swing together and change the confluence to a point up stream, leaving a hill isolated from the divide (Fig. 44, at D).

In cutting through the neck of a loop a deeply entrenched stream sometimes, by undermining from each side, forms a natural bridge. Other natural bridges are formed by solution or erosion of rocks by water above a waterfall working downward along joint planes, and probably by other methods. The best known American object of this sort is the Natural Bridge of Virginia, but it is vastly exceeded in magnitude by the Rainbow Bridge of Utah, with a span of 278 feet and height of 398 feet.

Along almost any rocky coast the isolation of hills by the action of the waves may be observed in every stage of the process (Figs. 42, 43). Finding vulnerable points where the rock yields more readily to repeated blows of the surf, the waves begin to cut channels into the sea cliff. Once begun, these channels gather the force of the waves and are driven rapidly inland. Two channels converge until only a narrow neck of land is left between them. Then the dashing waves break through the neck and form an arch. The arch widens under the steady pounding of the surf at each high tide, until the roof, deprived of sufficient support, falls in. This leaves a hill connected with the mainland by a low bar, which is covered by the surf at high tide. Erosion proceeds until the bar is covered even at low tide. The hill is then an island. As the sea cliff continues to recede, the island is left farther and farther from the mainland. The surf, beating on every side of the island, slowly reduces it until there are

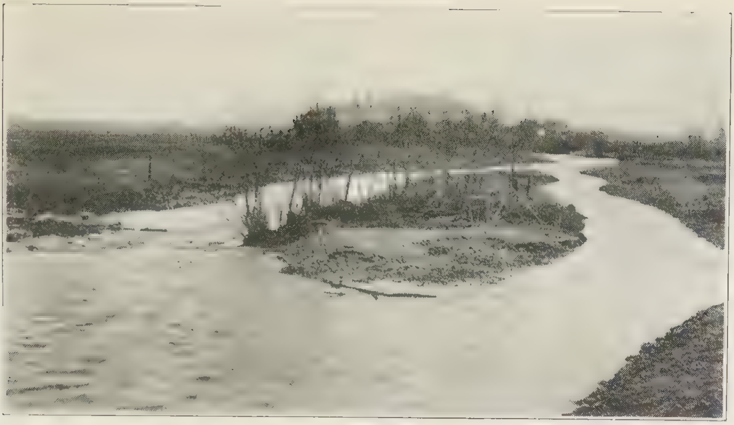

Fig. 45 — Island formed in a stream by the beginning of a new channel on the left during a flood.

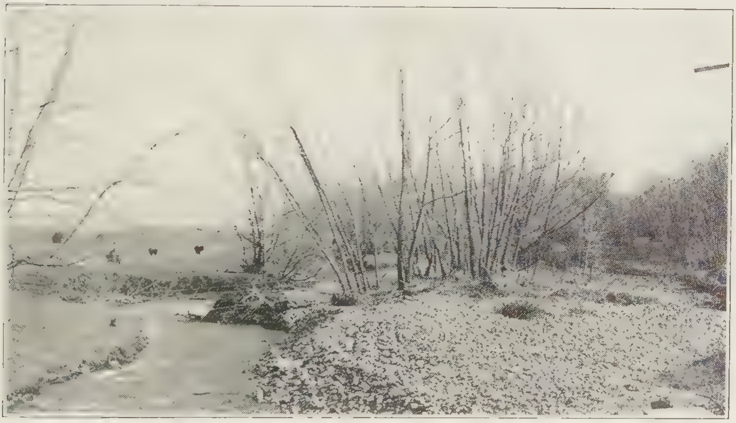

Fig. 46 — Same island ten years later, when the new left-hand channel has captured all the drainage.

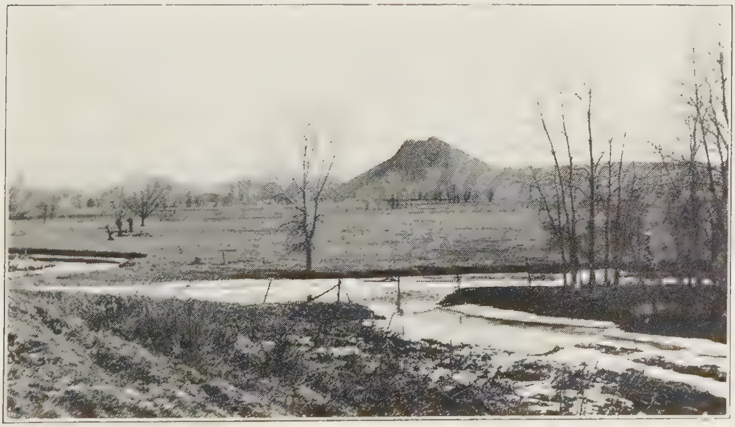

Fig. 47 — Valmont Butte, Colorado, a volcanic dyke forming a hill because of the erosion of soft formation which formerly surrounded it.

left only a few points projecting above the surface of the water. These soon disappear, leaving a covered reef, dangerous to shipping and dreaded by the sailor. This is the process that gives to us the rugged outlines of rocky coasts, with the surf breaking wildly over the jagged rocks during the wintry storms, or gently lapping them in times of calm, but ever at work in modifying the landscape (Fig. 68).

As the ocean seems determined to first create hills and islands, then tear down and destroy them, so with the river. A portion of the river in flood time finds a new channel, through which it flows, reaching the main stream again farther below, thus forming an island (Fig. 45). Then erosion attacks the island, and perhaps in time destroys it, or one channel deepening more rapidly than the other, captures the drainage, and leads the water all on one side, perhaps even partly filling the other channel (Fig. 46). In the latter way is Goat Island, in the Niagara River, seemingly destined to be deprived of its island character in the course of centuries. The cataract is receding more rapidly on the Canadian side than on the American side, as the gorge works up stream. If the recession of the falls continues on both sides at the present rate, obviously the gorge will reach the head of the island earlier upon one side than upon the other, and will capture the drainage, leaving a dry channel on the other side. This inevitable event need not worry the present generation, as it is reserved for a date far in the future.

The isolation of a hill resulting purely from differential erosion of a resistant local formation surrounded by a yielding formation, is particularly likely to occur in case of hard volcanic intrusions in soft shales. The scenic effects of erosion in such cases are sometimes quite striking (Figs. 47, 77, 94).

A distinguishing feature of rugged topography produced by stream erosion alone is that it is quite systematic. Shifting winds may build sand dunes without the slightest discoverable semblance of a system. This makes it easy for one to lose oneself in the desert of Sahara or amid western American sandhills. Running water is governed by laws that forbid such a result. Streams do not cross one another. Water seeks its level and always runs down hill. Hence it cuts its channels systematically from higher to lower ground, rivulets joining creeks, creeks flowing into rivers and rivers emptying into lakes or oceans. Storm waters dissecting a plateau or slope, act upon the same principle. Their channels, dry except following storms, converge as they progress down stream. At any point the water may start upon its course, and, ever flowing downward, reach the outlet of a river through a perfect drainage system (Fig. 48). So one may stand upon a mountain top and look out over the gorges, seeing not a haphazard arrangement of canyons, but a systematic arrangement, the main canyons and their laterals like the trunks of trees with their diverging branches.

From the earliest period of the earth's history as a globe with a solid surface, surrounded by an atmosphere and partly covered by water, erosion, made possible by folding and faulting, its effects varied by differing com-

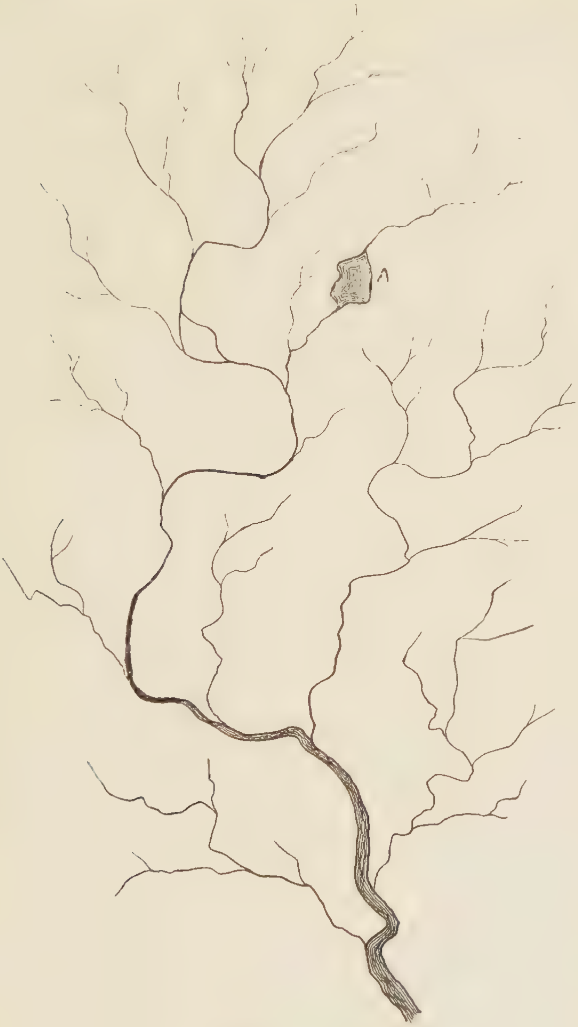

Fig. 48 — Diagram of a river system.

position and physical condition of the rocks, has been engaged in fashioning land forms, carving valleys and canyons, isolating hills and mountains, forming lakes, making soils, establishing coast lines and otherwise making and modifying scenery. Destroy all the results of the continuous operation for ages of these processes still at work, and we should have surroundings vastly different from the landscapes we now admire—a difference difficult to visualize, because one can scarcely imagine what a world would be like, free from the effects of erosion.

The River

"The river knows the way to the sea:
Without a pilot it runs and falls,
Blessing all lands with its charity."
EMERSON.

WHO does not love the flowing stream? Whether it be a majestic river sweeping silently onward to the ocean, a noisy mountain torrent hurrying on its journey to join the larger stream, or a babbling brook singing its song of delight as it murmurs from pool to pool to combine with other rivulets and form the mighty river. All have a common origin in the rains and snows that water the land, and nearly all have a common destination in the heaving ocean.

Rivers have figured extensively in the political, military, commercial, industrial, religious and aesthetic affairs of great nations. Statesmen early realized the importance of the control of all the country tributary to the Mississippi—the Father of Waters. The historic rivers of Europe and Asia have been the battlegrounds of nations. The Nile is the most important factor in the commercial and industrial life of Egypt. Barbarians have deified rivers, artists have painted them and poets have sung their praises.

A glance at the map will show how frequently streams form the boundaries of empires, kingdoms, republics, provinces, states and counties.

> "And scarce a name distinguishes the brook,
> Though rival kingdoms press its verdant sides."
> Lord Byron.

Only within recent times have boundaries been established by use of the surveyor's instruments, with purposeful reference to the cardinal points of the compass. This is strikingly illustrated by a comparison of the map of the newly-settled western portion of the United States with that of the older states of the eastern portion.

Drainage is the key to a landscape. This is just as true of the mountains as of the plains or the great valleys. So important is this fact that the traveller may more easily find his way in even the roughest region if he comprehends the drainage system and the principles underlying the establishment and maintenance of drainage, while the explorer unfamiliar with those principles labors under a great disadvantage.

As has been said, a river system may be likened to the trunk and branches of a tree (Fig. 48). Every rivulet, however small or intermittent, leads to a larger stream, many branches unite to form the main trunk, which eventually reaches some lake or the ocean. Even those streams which in arid regions flow no surface water during dry seasons, but content themselves with percolating slowly through the sand, still maintain more or less definite channels through which they sweep onward to the larger streams during times of flood.

River, rivulet and rill differ only in size, not in kind. There is no sharp dividing line between them. Indeed, many lakes are but wider portions of river channels

(Fig. 48, at A), the water flowing on more slowly through the wider portion and escaping through the continuation of the river, except in case of completely enclosed lakes of arid regions. The latter have no outlets and need none, because the amount of water received from precipitation and inflow does not exceed that lost by evaporation—the present condition of Great Salt Lake in Utah, the Dead Sea in Palestine and many others.

With drainage as the key, in working out the life history of its rivers, rivulets and intermittent drainage channels, one may unlock the secrets of a landscape. Thereupon it acquires new significance and becomes to us a thing of life and interest, because it has a history to relate and is still making history. The river has its periods of youth, of middle age, and of old age, just as human beings and nations have. In some portions of its course it may be in its youth, deepening its channel by erosion, as all streams heading in high mountains are doing in their upper reaches. In other portions it may have reached temporary base level, where it can neither deepen nor fill its valley, but is still able to carry off the debris arising from the widening of the valley by lateral erosion. In other portions its load of sediments derived from upstream erosion and the widening of its valley may have become too great to carry, so it is engaged in refilling the valley by deposition of a portion of the load.

In semi-arid regions, where soft shales and alluvial deposits are extensively exposed to erosion, with steep slopes unprotected by vegetation, splendid opportunities are afforded for the study of the beginnings of drainage systems. Water, seeking its level in response to the law of gravitation, runs down hill. The waters from a violent summer rain unite into a tiny rivulet on a steep slope and cut a small channel. The depth of the channel rapidly increases with successive storms. Its length also increases as it works its way farther and farther into the slope. The cutting of the channel makes two new slopes upon which erosion may begin its work, one on each side of the channel. Rivulets on these newly-made slopes begin to cut channels connecting with and draining into the one first made. Upon the slopes of the branch channels others begin to cut. All these progress headward, forming not a confused network, but a perfect system, all tributaries leading finally to the main trunk, which, as it receives more and more drainage from the increasing branches, and perhaps by cutting downward to the level of permanent ground water, grows in size until it assumes the proportions of a creek. Instead of carrying only storm waters, as at first, by increasing its drainage area and its collecting power it becomes a perennial stream. As the main valley expands laterally it may obliterate many of the smaller tributaries, or several of them by their own lateral expansion may unite into one valley.

Rivers in a rocky, mountainous country, where the grade is great and the currents swift, are more likely to abound in straight stretches of considerable length than those on alluvial plains. Alluvial valley streams move forward by graceful, sweeping curves (Figs. 49, 50). If we could suppose a river to now flow through a flat alluvial valley in a perfectly straight course, it would

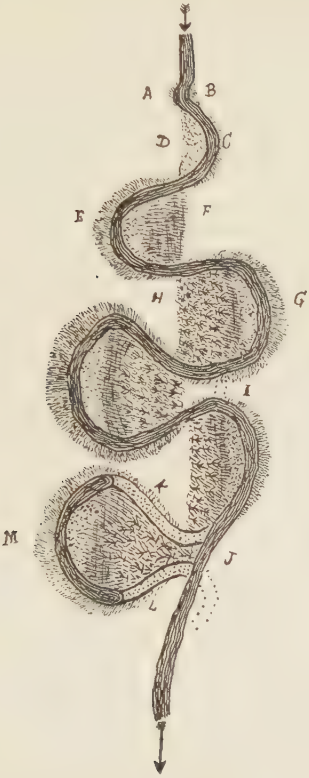

Fig. 49 — Diagram showing creation and destruction of ox-bow loops by a stream. *A, B,* initial stage of a loop, cutting at *A,* filling at *B.* *C, D,* a loop at a more advanced stage, cutting at *C,* filling at *D.* *E, F,* a more advanced stage, vegetation established on filled ground at *F.* *G, H,* loop well formed, trees established at *H.* *I,* loop nearly completed. *J,* stream has cut through neck of loop, shortening the stream channel. *K, L,* old channel filling with silt near the stream, leaving a bayou at *M.*

not long continue to do so. Through unequal erosion it would soon begin to wander, sweeping from side to side by a very simple process, as it flows onward to the sea.

The river finds an easily eroded spot and cuts into the bank at that point· As the sluggish current swings into the bank it is deflected and thrown against the opposite bank a short distance below, into which it cuts and is again deflected (Fig. 51), and so successive curves are formed down stream (Fig. 49). Meantime, at each curve, on the convex side where the current is strongest, it forms a steep bank by undermining. As the current swings to the outside of the curve its velocity is reduced on the inside, and it drops part of its load, forming a sand or gravel bar (Figs. 49, 51). As cutting on the outside proceeds, the bar increases in height and extends farther out (Fig. 51), constantly following the opposite bank in its advance. In this manner the stream is kept at approximately the same width, instead of widening into a lake by the cutting away of one bank without shifting the other. As time rolls on, each curve increases until it nearly forms a loop. As each loop continues to enlarge, its ends come closer together, until at last, probably in flood time, the stream breaks through the narrow neck and straightens the channel at that point, in preparation for a new cycle of meandering. The ends of the broken loop then fill up, because the current there spreads out and is sluggish, forming a bayou such as is common in the valleys of rivers flowing through flat alluvial regions. In the building of the bar on the inside of the loop, as it becomes larger and older it is covered by vegetation, and finally by trees in a region favorable to tree growth. When the final process isolates the bayou it is still subject to the action of floods for some

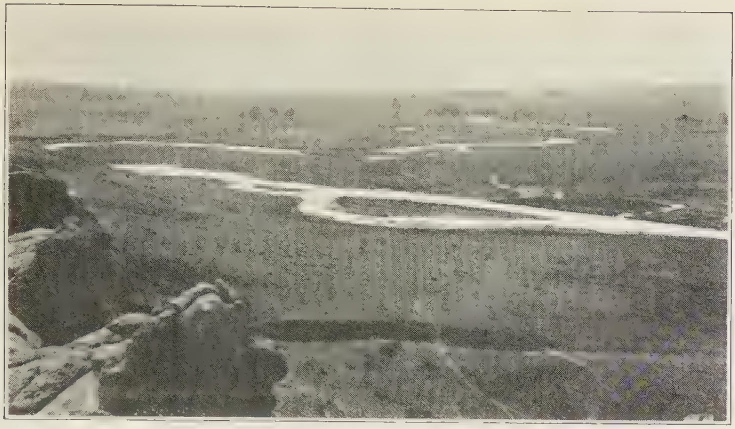

Fig. 50 — A meandering stream in a flat alluvial valley.

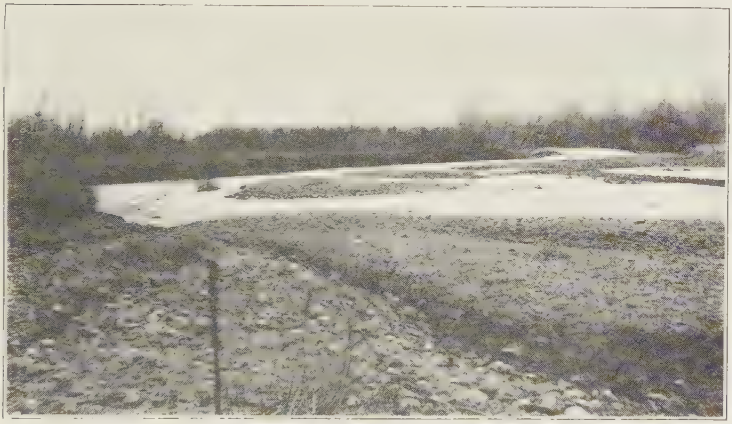

Fig. 51 — A stream cutting into one bank and building out from the other, thus preserving a constant width of channel.

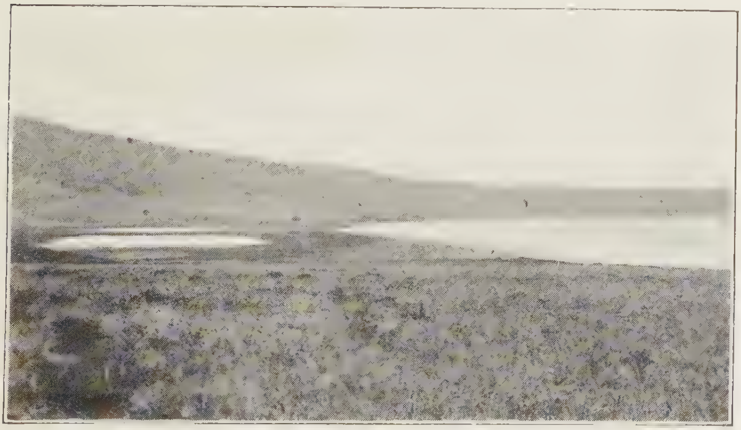

Fig. 52 — Lakes formed by a barrier beach along the seashore.

time and may in the course of time become entirely filled with sediments, thus destroying the evidence of its former existence. In some regions this entire process may be followed through within the lifetime of one human being, who may observe its every stage and watch the gradual transformation of the landscape. From the abandoned banks and bayous we may partially read the recent history of a river's oscillations. The continual shifting of the river from one side of its valley to the other, accompanied by the deepening, widening or filling of the valley, may, on the other hand, obliterate all the old landmarks and in so doing establish new landmarks from which only the very recent events may be ascertained.

As a river above base level, flowing through yielding material, and therefore rapidly deepening its channel, swings from side to side, it cuts into the bank, forming a

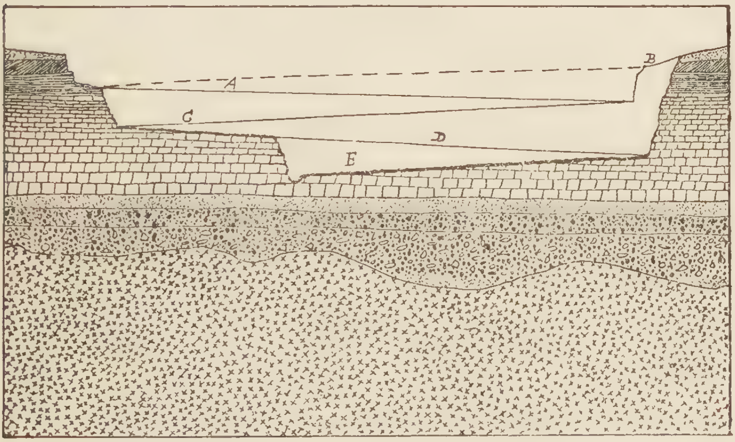

Fig. 53 — Diagram showing production of terraces by stream swinging back and forth across its valley as it cuts steadily downward.

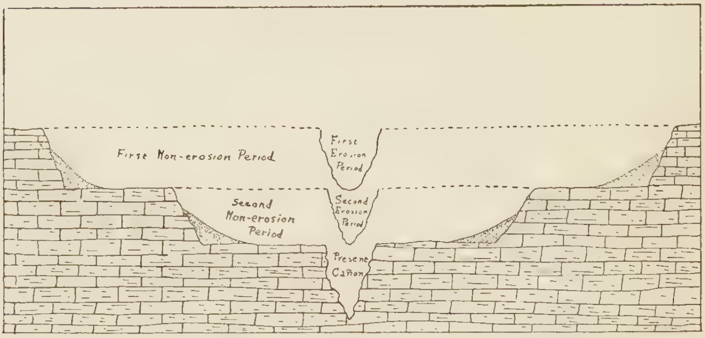

FIG. 54 — Diagram showing paired terraces produced by alternating periods of vertical erosion and non-erosion in homogeneous rocks. Valley continues to widen when downward cutting ceases.

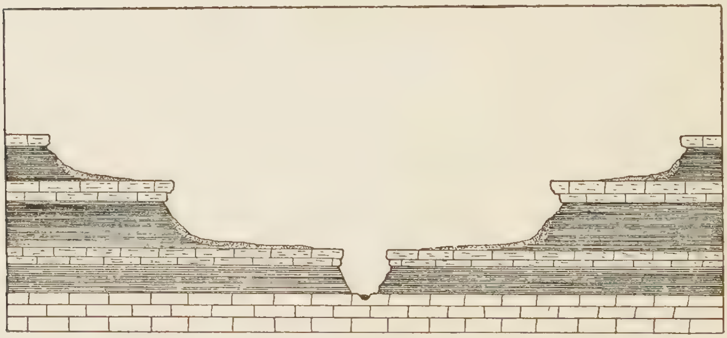

FIG. 55 — Paired terraces resulting from continuous downward cutting in alternating hard and soft strata, the valley widening by lateral erosion in soft strata during periods when vertical erosion is proceeding slowly in hard strata.

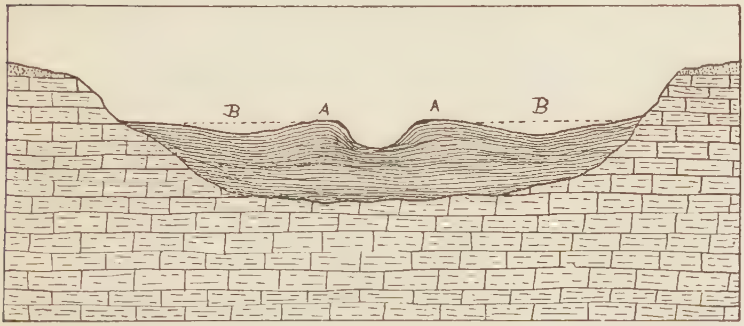

FIG. 56 — Diagram showing a section across the valley of an agrading stream, with vertical scale purposely exaggerated, to illustrate river swamps. *A, A,* banks of stream on which most of the sediment is deposited during floods, thus building up the banks, leaving lowlands to form swamps away from the stream at *B, B.*

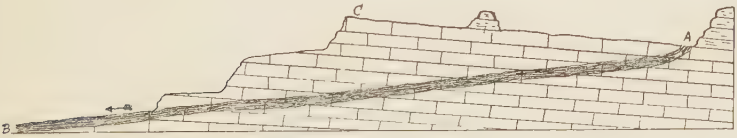

FIG. 57 — Diagram showing "persistence of rivers," the strata being slowly tilted so as to dip up stream as the rapid downward cutting of the canyon progresses, giving the impression that the stream must have flowed up-hill before the canyon got so deep.

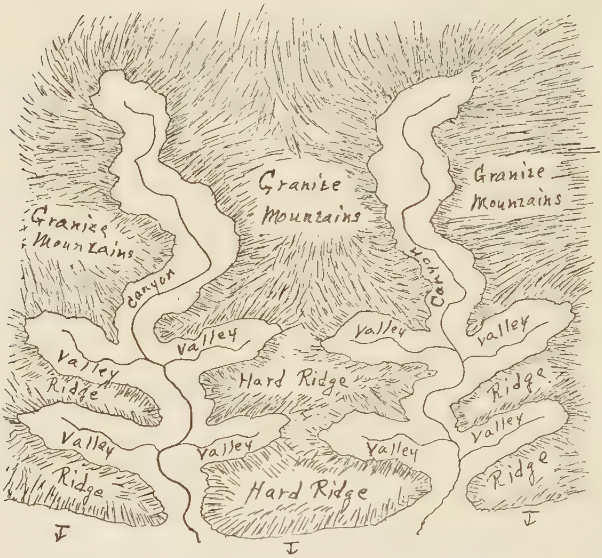

FIG. 58 — Diagram showing "persistence of rivers." Streams having started to cut channels, reach alternating hard and soft zones in their downward progress, but continue to cut downward along the same lines. Afterwards alternating valleys and ridges are formed by lateral erosion of the soft zones, giving the impression that the streams cut their channels through the ridges, instead of starting them before the ridges were formed.

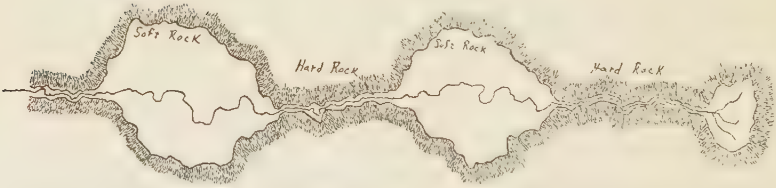

FIG. 59 — Diagram showing alternating narrow gorges and wide valleys formed by rapid lateral erosion in soft zones while vertical erosion proceeds slowly in hard rocks.

bluff or terrace (Fig. 53). Later, still cutting downward, it swings back to the other side of the valley and forms another terrace, whose base is lower than the first. Again swinging across the valley, it may either form a new terrace at a lower level than the first, or, if the process be long enough continued, it may undermine and destroy the first one, leaving a single high bluff.

River terraces may be formed in various other ways. A stream cutting downward through sandstones differing but little in their resistance to erosion may reach approximate base level, when rapid downward cutting must cease. Lateral erosion continuing, by the action of storms and frost, the valley is much widened. Then a general uplift raises the region again far above base level and a new cycle of downward erosion begins (Fig. 54). Reaching base level, again the valley is widened as before. Another uplift may then begin a third cycle of downward erosion. Thus by a series of uplifts and base level periods a series of terraces is formed, each pair being on a common level. The resulting topography is very different from terraces formed by the swinging of the stream from side to side as it cuts downward. Paired terraces may also be formed by continued downward cutting where the formations are horizontal and composed of alternating resistant and non-resistant strata (Fig. 55). Cutting rapidly through soft shales, the stream reaches a hard sandstone in which progress is slow. While cutting through the sandstone the valley is greatly widened by lateral erosion. Passing through the next soft stratum the process is repeated, and so on. Remarkable examples of the receding terrace topography may be seen in the Grand Canyon of the Colorado.

River terraces often present a view of striking beauty as the rays of the rising or setting sun bring them out in strong relief, for light and shade is the magic wand by which Nature puts life into many a landscape that is dull and uninteresting under the full glare of the noonday sun.

Care should be taken not to confuse stream-formed terraces with lake terraces and sea cliffs, which are quite different in their nature and usually easily distinguished, though in their scenic effects and general appearance they bear much resemblance.

In the broad valley of a sluggish river flowing through an alluvial country and engaged in building up its valley, the river swamp is of considerable importance, from the geological and scenic point of view, as well as having a very practical bearing upon the welfare of the inhabitants of the valley. The swamp is likely to occur, not near the river bank, where it might be expected, but far away at the edges of the valley (Fig. 56). The explanation drawn from a consideration of the principles of erosion and the transportation of sediments by running water, is simple, and is confirmed by observations in the field. During each flood the amount of sediment carried by the stream is temporarily increased by the mud and sand washed in from the surrounding region. In the ordinary channel the current is swift enough to bear the burden. The moment the stream overflows its banks the current of the overflow is checked by spreading out over a larger area, and deposits the coarser and heavier materials constituting the greater part of its load upon or near the banks, reserving only the finer and lighter material to deposit out near the edges of the valley. Thus the banks are built above the more distant portions of the valley, leaving the latter in a low swampy condition, where forms of vegetation peculiar to marshes abound in rank profusion. When the banks are raised too high above the swamps the main current of the river is likely to cut through and adopt the swamp as its channel. Then in time the new channel, by the same process, will build up its banks and channel above the adjacent portions of the valley. The entire valley may be filled up in this way, but the equilibrium is such that the banks will maintain about the same relation to the swamps. The river Po, in Italy, is said to have raised its banks above the tops of the houses in some parts of its valley, and fears have been expressed that eventually the levees of the Mississippi may be raised to such a height as to become exceedingly dangerous.

A river may either grow or shrink. Its growth is accomplished by headward progression and the capture of additional drainage, or by building a delta out into lake or ocean, thus forming new land through which it must wander to reach its outlet. It is estimated that the Mississippi each year discharges into the Gulf of Mexico seven or eight billion cubic feet of solid matter (not including the millions of tons of matter in solution), sufficient to cover one square mile to a depth of 241 feet, or 241 square miles to a depth of one foot. A river may shrink by the encroachment of the ocean through the subsidence of its delta or otherwise, or by the capture of some of its drainage, especially its headwater drainage, by other streams.

In the consideration of some of our grandest scenery the principle known as the persistence of rivers is involved· The river, having entrenched itself deeply, continues to cut downward along about the same line, and is not as easily deflected from its course as it is when its channel is shallow. The traveller finds a stream flowing through a deep gorge where the rocks and the general surface of the country dips up stream. He cannot assume that the stream flowed up hill when it began the cutting of its gorge, as that would be quite contrary to the eternal laws of Nature. In some instances the explanation is that the swift stream was well entrenched, with steep grade and rapid current, when the tilting of the strata began, and the tilting process was so slow that the downward cutting was not interrupted (Fig. 57). The traveller may find a stream passing directly through a high ridge by means of a deep canyon. He cannot assume that the water flowed up over the ridge to begin the cutting of its gorge. It will often be found in such cases that the ridge has been formed by lateral streams cutting away soft material after the main stream had carved its way downward deep into the hard rocks (Fig. 58). Alternating wide valleys and narrow canyons are sometimes found along the course of a stream, particularly in granitic mountains (Fig. 59). The stream, in its downward cutting, meets a hard zone of rock, perhaps an igneous dike, through which its progress is very slow. While it is slowly working through the hard rock, lateral erosion widens the valley in the softer rock up stream, the resulting debris furnishing the sand and gravel used by the current in grinding its way through the hard zone. The park-like valleys produced by this process are often easily mistaken for the beds of extinct mountain lakes.

Thus the river, with all its changes, its meandering, cutting and filling, making and tearing down terraces, building and destroying formations, flowing on its course through untold centuries of the past and destined to flow through unnumbered centuries of the future, writing its history upon the very rocks through which it carves its way, becomes to the student of Nature a thing of life and beauty. In its early career it begins to grind its way into the rising land, possessed of the vigor of youth and entering earnestly into the work of reducing its valley to base level. With increased age comes decreased power, until it is no longer able to deepen its channel, but rolls lazily on to the ocean through a broad, open valley, bounded by the low, rounded hills characteristic of aged topography, contrasting strongly with the more angular topography of youthful landscapes.

The poet has caused the brook to say:

"Men may come and men may go,
But I go on forever."

Ah! What a mistake! For brooks have come and brooks have gone. Then what assurance have we that the brook now murmuring through the peaceful meadow and adding so much to the beauty of the landscape may not some day be numbered with the dead?

We look out over the broad valley and note the graceful curves of the winding stream, its tree-clad banks, its swamps, its bayous, its delta, its terraces, its numberless tributaries, its lakes, its cataracts, and the more rugged topography and deep gorges of its upper reaches. When we recall that all this variety of scenery is the result of geological processes in operation through the by-gone ages and still proceeding in orderly fashion with their work, we are convinced, by this exhibition, of the power of Nature's silent, almost unnoticed forces. If we subtract from the landscape its geological phenomena and the indirect results of geological processes and agencies, what have we left?

The Waterfall

"If eyes were made for seeing,
Then Beauty is its own excuse for being."
EMERSON.

A WATERFALL is but a small part, though from a scenic point of view a tremendously important part, of a river system. Niagara, with its thunderous roar and mighty power, has astonished the world. Minnehaha, with its less vigorous beauty, has inspired the poet. Yosemite, with its dizzy height and veil of spray, has enticed the artist. All these have echoed the tourist's praises, have been impressed upon the sensitized plate by thousands of admirers, and have been reproduced upon the painter's canvas as accepted facts, with perhaps very little thought as to their causes. Scattered through the mountains of the East and the West, and in the most remote corners of the world, are scores of cataracts as captivating as any of these, all bearing evidence of the operation of Nature's laws, a knowledge of which must surely add to one's interest in them. Some of the most delightful of waterfalls seldom meet the gaze of man, because the very conditions that make them possible also make travel so difficult that none but the enthusiast ventures upon the task of their discovery. No definite line of demarkation separates waterfalls into classes in accordance with their magnitude. They exist in unbroken series from a mere ripple caused by a slight increase in the slope of a rivulet bed, to a roaring torrent whose waters plunge from a lofty precipice scores of feet to the vale below, the spray breaking up the sun's rays and reflecting them in all the colors of the rainbow. They may, however, be roughly classified with regard to their origin and the causes permitting their continuance. Especially may most of the falls that attract the attention of landscape students be, from the scenic point of view, divided into two groups. One, with Niagara as the type, is characterized by the maintenance of a perpendicular front. It is found where streams flow over broad sheets of nearly horizontal strata of hard rock, underlaid by more easily eroded strata. The other, more characteristic of a mountainous region, including all whose origin is not due to softer strata underlying hard horizontal strata, is not characterized by the preservation of a vertical front as it retreats up stream under the influence of erosion.

With Niagara as a type, it is easy to see how it is possible for it to recede up stream and still always retain its character as a perpendicular waterfall, and through the comprehension of the principle involved, to also understand Minnehaha, St. Anthony and other falls of the same sort·

Almost from the beginning of civilized man's acquaintance with Niagara it has been the dream of engineers to harness the cataract and set it to work in the interests of the industrial world. Ages before the white man first saw it, perhaps even before the aboriginal

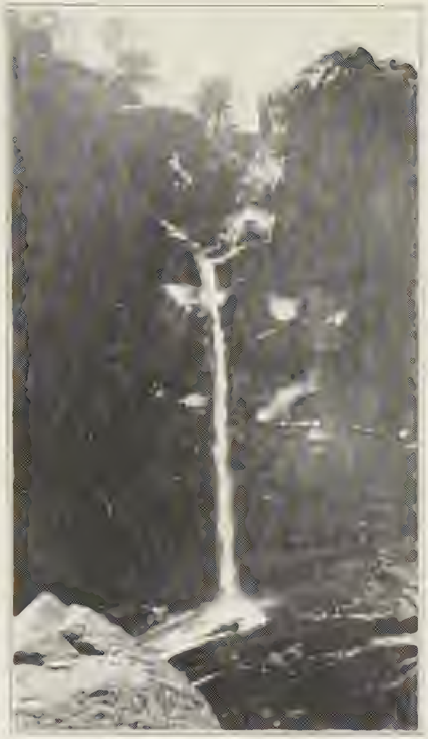

Fig. 60 — Box Elder Falls, Colorado, due to the breaking of the rock from a vertical cliff along a joint plane.

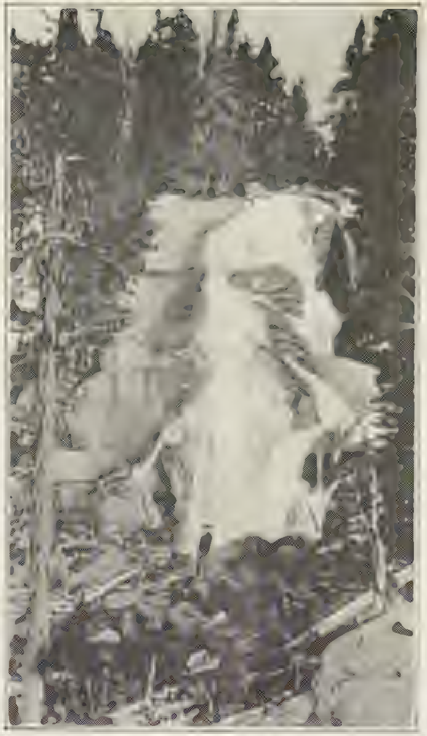

Fig. 61 — North Boulder Falls, due to a hard mass of rock extending across a glaciated valley.

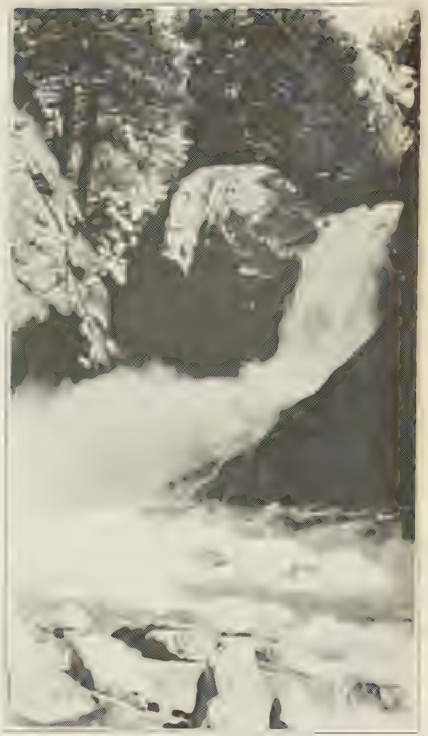

Fig. 62 — Boulder Falls, occupying a "hanging valley" caused by the more rapid cutting of the main canyon than of its tributary.

human inhabitants of America had witnessed its wonders, its lavish power was going to waste, in a commercial sense of the word, but it was busily engaged in making the splendid gorge through which the river now flows onward after dashing over the precipice. In by-gone times, flowing tranquilly through a comparatively level plain, the river suddenly dropped over the edge of the escarpment at Lewiston, seven miles from the present site of the falls. The spray and the winter's frosts, wearing away the soft shales beneath, undermine the hard capping-rock, until the weight of the overhanging rock is too great to be sustained, and it breaks along joint planes, the fragments falling into the gorge below. Thus, foot by foot, the precipice has receded up the river, leaving the deep gorge to mark the course of its journey. At a very early date it became known that the precipice had retreated from the edge of the Ontario plateau and was still slowly moving up stream. With this knowledge came the hope that by careful measurements of the present rate of recession, it might be possible to estimate in centuries, if not in years, the time required by Nature to perform this one small portion of her task in bringing the earth to its present condition, and perhaps also incidentally to ascertain the length of time that has elapsed since the retreat of the great continental glacier from that region. So measurements have been made from time to time and records kept, from which it is ascertained that the average rate of recession for forty-two years was three feet per annum. Several acres of the unsupported shelf broke off at one time and fell with a crash to the bottom of the gorge, there to be ground to pieces by the work of the falling water. It is also known that the Canadian side is now receding much more rapidly than the American side. With such definite data at hand, it would seem at first glance purely a matter of simple mathematical calculation to estimate the time necessary for the carving of the gorge, yet the estimates have ranged all the way from 7,000 to 200,000 years. We cannot assume that all of the factors of erosion have remained the same all these centuries. Is the volume of water the same? Are the rocks of exactly the same hardness and jointed structure all along the way? Has the gradient remained the same? Have earthquakes of sufficient force to assist in breaking off the cap-rock been more frequent or less frequent in the past? What is the effect of the division of the stream by Goat Island upon the rate of erosion? How much, if any, change of climate has there been? The value of these and other factors is unknown. That is true of most attempts to estimate geological time except relatively. We may ascertain that certain events have happened, the order in which they happened, and, their results within reasonable limits, but may not know in years or centuries the amount of time required.

Where alternating hard and soft strata occur in horizontal position, a beautiful series of low falls may be developed. Vertical falls may develop in a region where the strata are tilted to a very high angle, if a hard ledge underlaid by soft material dips up stream, but such a fall would disappear before it had receded very far.

A very common form of the mountain type of cataract, is caused by the more rapid cutting of the main channel, either by stream or glacial erosion, leaving the bed of the tributary at a higher level at the point of confluence, so that the water from the tributary comes tumbling over a precipice (Fig. 62). The tributary valley left at a higher level by the over-deepening of the main valley is called a "hanging valley." Such valleys, with their cataracts, are especially common in the higher glaciated mountains. Sometimes, in a massive sandstone, from the breaking of the rock into a vertical face because of jointed structure, a vertical fall may result (Fig. 60), but it would soon lose that character as it recedes.

In a granitic mountain range there are often hard zones of rock. A stream or glacier passing over such a hard zone, will excavate more rapidly below it, and thus form a cataract, but it will not be a vertical drop except under exceptional circumstances. In many such cases the water leaps from rock to rock, from ledge to ledge (Fig. 61), in a series of sparkling cascades, varying in appearance from hour to hour with the changing conditions of light and shade, but always beautiful. This type of waterfall grades imperceptibly into rapids, formed by a series of small cascades, between which and a slight ripple there is no sharply-drawn dividing line. One familiar with the process by which falls recede is ever mindful that they are engaged in slowly but surely committing suicide.

All streams are engaged, if one may again use an anthropomorphic term, in an effort to establish a constant grade from source to mouth of just sufficient degree to prevent either cutting or filling. In other words they are seeking base level. It is therefore evident that cataracts, especially the mountain type, are characteristic of youthful or rejuvenated topography. It is also evident that as base level is first attained in the lower portions of the stream, cataracts are more likely to be found in the upper portions of the water courses, and almost always to be expected in a mountainous country. Thus the lower Mississippi is a slow and majestic stream, without waterfalls or rapids. Toward the headwaters it and its tributaries abound more or less in cataracts, as at St. Anthony· Following larger tributaries to the westward up into the Rocky Mountains, in the more rugged portions they become almost an unbroken series of rapids and waterfalls.

There is something about rushing water that is wonderfully attractive to human beings. No scenic feature is more popular than a waterfall. Hence among the more important geological processes connected with the production and modification of landscapes must be numbered those engaged in forming and maintaining cataracts.

"Flow on forever in thy glorious robe
Of terror and of beauty; . . . God hath set
His rainbow on thy forehead; And the cloud
Mantles around thy feet. And he doth give
Thy voice of thunder power to speak of Him

Eternally, bidding the lip of man
Keep silence, and upon thy rocky altar pour
Incense of awe-struck praise."

MRS. SIGOURNEY: *Niagara.*

The Lake

"O, Nature! Gracious mother of us all,
Within thy bosom myriad secrets lie
Which thou surrenderest to the patient eye
That seeks and waits."

MARGARET J. PRESTON.

LANDSCAPE artists delight in lily-decked, rush-fringed ponds and pleasant stretches of lake shore with which to enliven their paintings. If a lake is the controlling element in a charming bit of scenery, it may still be maintained that drainage is the key by which the mysteries of the landscape may be unlocked. If we except those fed entirely by springs, how could a lake exist were it not for the drainage system—the rivers and rills that gather the rains and snows from the highlands and conduct them to a common reservoir? Indeed, a lake is in many cases but a wider portion of a stream (Fig. 48, at A). As drainage is also the great destroyer of lakes, they in part owe their continued existence to the fact that the streams have not been too long at their work of sedimentation and of cutting down the outlet. Some of the vast Pleistocene lakes, such as Lake Lahonton (of which Pyramid, Winnemucca, Walker, Carson, Humboldt and Honey Lakes, in Nevada and California, are very much reduced remnants), and Lake Bonneville (of which Great Salt Lake and Provo Lake in Utah are

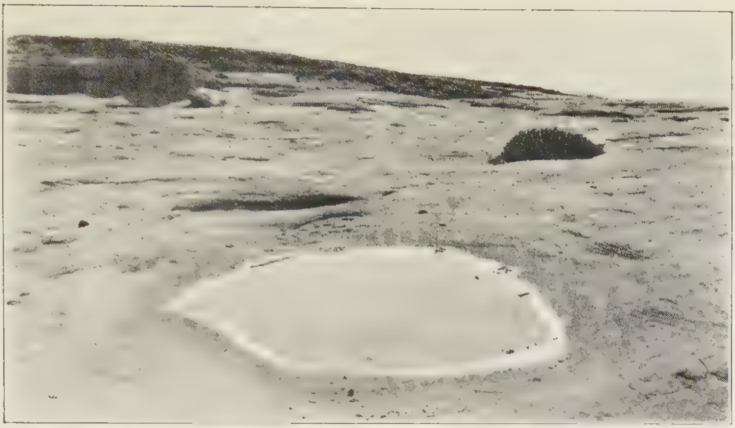

Fig. 63 — Lakelet formed in hard sandstone by aeolian erosion.

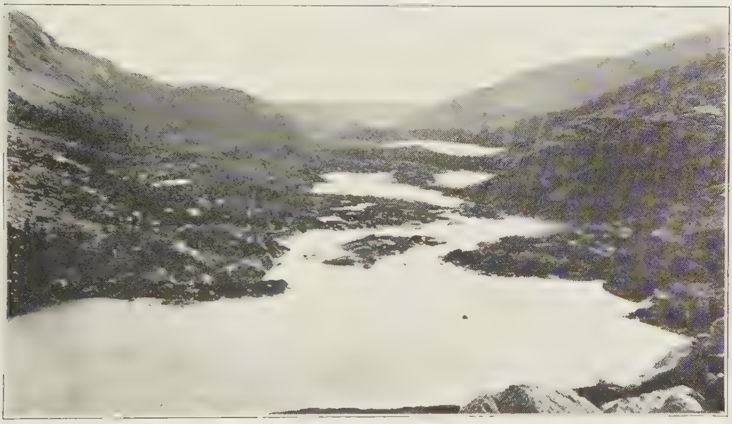

Fig. 64 — Chain of glacial lakes below Arapahoe Glacier.

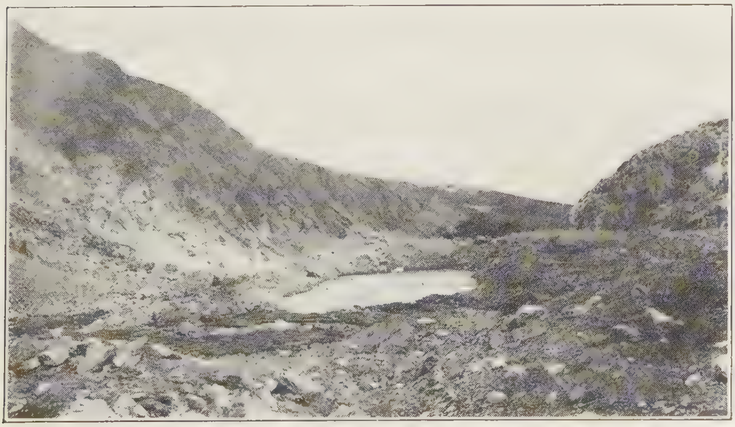

Fig. 65 — Lake formed by an ancient moraine below Arapahoe Glacier.

shrunken relics), for centuries dominated the regions in which they existed. Very small mountain ranges west, northwest and southwest of Salt Lake City were once islands or promontories projecting into the great Pleistocene Lake Bonneville, just as some smaller ones are now islands or promontories in Great Salt Lake. Manifestly the reduction of the lake to its present dimensions within a recent period has produced a profound change in the scenery of an enormous area.

In general, lakes may be considered mere passing incidents in the geological history of their localities, whose ephemeral existence is not to be compared with that of river and mountain systems.

As the growth of vegetation and the rate of erosion, rock decay and other geological phenomena are extensively influenced by climate, large, deep lakes have an important bearing upon scenery, indirectly in their more or less marked local effect upon climate, in addition to their direct effect as integral features of the landscape. All dwellers on lake shores are familiar with the difference in temperature and humidity between a land breeze and a lake breeze·

> ". . . a lake behind
> Improves the keenness of the northern wind."
>
> Pope.

Winter and summer the breezes affect the temperature of the immediate vicinity, as well as the humidity of the atmosphere, though their influence in these respects is not as profound and is not felt as far inland as has sometimes been supposed.

Lakes act as regulators of rivers. Flood waters of the tributary streams spread out over the wider surface of the lakes, gradually flow through and escape so slowly as to cause little damage along the banks of their outlets. Thus the St. Lawrence, bearing away the flood waters of all the streams pouring into the Great Lakes, never spreads out over the adjacent land with the disastrous results so common along the Ohio, Mississippi and other rivers that have no great lakes to act as safety valves. Lakes are also settling reservoirs. Turbid streams entering a lake drop their loads of sediment with the checking of the current as the water spreads out, and flow on clear and free from sediment, unless again rendered turbid by local conditions near the outlet. At the foot of a glacier the water, as it reaches the first small lake, is white as milk with the "rock flour" ground from the rocks by the moving ice. In the first lake it drops much of its load, but may retain the finer and lighter part, flowing on to a second lake, still strongly colored. With each successive lake it becomes clearer, until, after flowing on down the valley through a series of such reservoirs, it finally emerges so clear and pure that not a trace of the original color may be detected.

Lakes are of all sizes, from the roadside pool born of a sudden shower and dying as soon as the fierce rays of the sun reach its surface, to the great inland seas existing through unknown centuries and bearing upon their bosoms the commerce of nations. There is no hard and fast line dividing them according to size. A body of water that is called a pond in the region of the Great

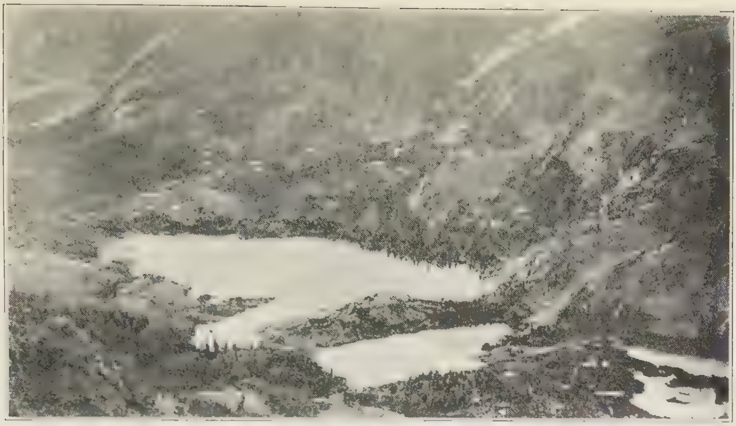

Fig. 66 — A glacial rock basin, showing lake and *roches moutonnées.*

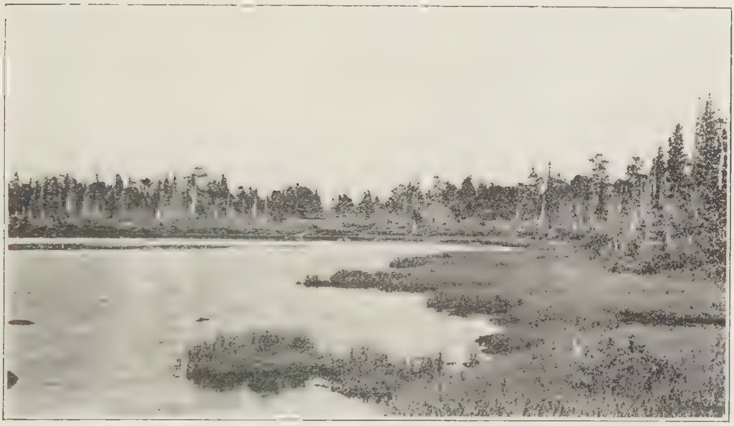

Fig. 67 — Vegetation filling a mountain lake by building out from the shore.

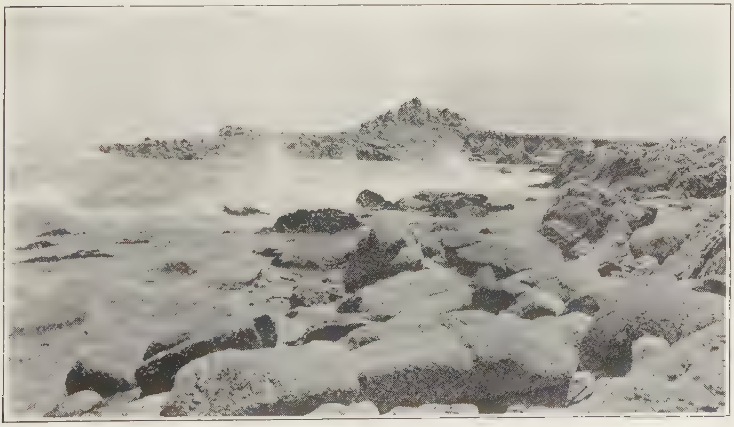

Fig. 68 — Surf beating on a rock-bound coast.

Lakes is a lake in an otherwise lakeless country. The ocean itself is essentially a great lake, its waters made saline by the salts carried in by numerous rivers, the evaporation of water from the surface leaving the salts in somewhat concentrated solution. Probably the largest body of fresh water now in existence on the earth's surface is Lake Superior, with an area of approximately 33,000 square miles. Lake Victoria Nyanza, in Africa, comes next, with an area that has been estimated at more than 32,000 square miles. Lakes Michigan and Huron cover about 23,000 square miles each. The largest saline lake is Caspian Sea, with no direct open communication with the ocean. The lakes drained by the St. Lawrence form the greatest group of lakes in the world and well deserve their common appellation, "The Great Lakes." They contain sufficient water to maintain the flow of Niagara at its present stage for a century, if it could all get over the various barriers.

Lakes have life histories, just as rivers, mountains, men and nations have. They have their periods of youth, passing through maturity to old age and finally to death. The history of each differs a little in detail from that of others, but all have points of resemblance. They are so alike in their reaction to like conditions that from a knowledge of the principles and conditions governing their establishment, maintenance and destruction one may generally with a considerable degree of certainty ascertain the chief points in their past history, and with some confidence predict their future. The wavelets caused by passing breezes upon the surface of a shower-formed pool in fine soil, may build beaches and terraces in all but size resembling those built by the surging billows of a lake many square miles in area. Though alike in many respects, lakes differ radically in their origin and in the causes of their destruction.

On the great semi-arid plains of the West, pioneers penetrating that unexplored region many years ago found numerous round basins in the fine soil of the dry divides, from six feet to several rods in diameter. They were caused by the tramping and wallowing of bison in the mud of very shallow wind-formed depressions, or depressions formed by pawing after rain or snow storms. Each animal carried away a small quantity of mud entangled in its long hair, thus slowly deepening the depression and packing the bottom clay by rolling and treading upon it until it formed an impervious layer. In these depressions water collected during every storm and remained until dissipated by the rays of the sun and absorbed by the dry atmosphere as by a sponge. To these depressions explorers and settlers gave the name "buffalo wallows," suggested by their origin. They were of much importance to the herds that once roamed the plains, where water is scarce and streams far apart, and afforded some relief to the monotony of the landscape on flat divides otherwise devoid of water. Alas! The picturesque herds of bison have disappeared before death-dealing rifles in the hands of "civilized" men, and with them have gone most of the unique depressions that once dotted the plains.

The "water-holes" in channels of western intermittent streams, with sides and bottoms of impervious shales that prevent the escape of water by percolation, appear to owe their origin at least partly to the same cause. They have not disappeared because domestic cattle introduced by the settlers resort to them in the same manner as did the bison, treading the mud, if not wallowing in it. From these small reservoirs, holding water after each storm (the larger holes retaining a perennial supply, often furnishing the only water to be found for long distances), the stockman's cattle now slake their thirst, as the herds of bison did before their extermination. They are miniature lakes, of consequence quite disproportionate to their size in a region where water is not plentiful, and add to the landscape the only bits of brightness in great expanses of territory.

The largest lakes are the result of the wrinkling of the earth's crust. We have seen that the earth's surface is unstable, ever changing, folding, warping and breaking. Inevitably continual warping as the ages roll by must result in the production of rock basins capable of retaining water, unless other causes succeed in destroying the basins as rapidly as the warping proceeds. A fold or fault block rising across the course of a river must surely hold back the water and form a lake, unless the persistent downward cutting of the channel proceeds with sufficient rapidity to keep pace with the elevation of the obstacle. The Tertiary Lake Florissant, in which was deposited a formation that yields very numerous fossil plants and insects of extinct species, was formed in just that way, then drained and destroyed by continued warping that reversed the drainage and caused the lake to overflow at the other end, where the new outlet cut down the barrier until it provided complete drainage for the basin. Warping of the strata contributed to the formation and modification of the Great Lakes. Warping and faulting on a large scale produced those great basins once occupied by ancient Lake Lahonton, with an area of 8,000 square miles, and Lake Bonneville, with an area of 20,000 square miles. It is said that Lake Champlain was isolated from the ocean by the rise of now intervening land, its waters having been freshened by overflow and replenishment from fresh-water streams.

Ephemeral lakes form in wet seasons in shallow depressions caused by unequal weathering of soil or rocks (Fig. 63), particularly where soft formations not well protected by vegetation are constantly exposed to atmospheric action. If the decomposed material is all carried away by running water, obviously no lake can be formed, as the water could not remove material from much below the level of its outlet, and the stream-cut channel would drain the basin. Where loosened materials are borne away by the wind, basins are formed that fill with water during wet weather and are desiccated in dry seasons, often leaving in their beds a coating of alkali as white as freshly-fallen snow, consisting of the salts leached from the soil, carried into the basins by the storm waters flowing in, and left by evaporation.

The production of lakes by the wind is not confined to this destructive process. By building sand dunes, especially along sea and lake shores, winds are ever at work enclosing basins in which lakelets may nestle, adding greatly to the picturesqueness of their surroundings. Many of the potash lakes that have developed such economic value in recent years occupy wind-formed basins, the result of wind erosion and the building of sand dunes. By the combined action of wind and wave along the seashore, barriers are often constructed which hold back the waters drained from adjacent land, thus forming fresh-water lakelets in close proximity to the briny ocean (Fig. 52). Spits and sandbars built by waves and shore currents cut off portions of lakes and seas, forming lagoons or small lakes, partly or wholly land-locked. The changing of river channels, cutting through the necks of river bends, leaves ox-bow bayous (Fig. 49), which are true lakes, reaching considerable size in the valleys of large rivers. Though the tendency is for rivers to prevent the formation of lakes and to destroy them when formed, there is at least one way, in addition to the isolation of bayous, in which a stream may itself be the active agency in the production of a short-lived lake. When the rapid current of a high grade stream in flood, carrying large quantities of sand and gravel, enters a stream of such low grade that the sluggish current is unable to remove the detritus as rapidly as it is received, the accumulated material may form a dam behind which the water gathers until it acquires sufficient power to break or cut through the barrier.

In some regions dams thrown across streams by beaver, in their instinctive efforts to provide suitable environment for their winter residences, retain lakes which are important features of the landscape and exercise a marked influence upon trees and other vegetation. Though this very interesting animal has become rather rare over large portions of its former range, through the destructive activities of the fur trade, its ponds still dot many of the valleys of the Rocky Mountains where aspens and other deciduous trees occur, often mingling with glacial lakes in the higher portions. A dam accidentally formed by the lodgement of driftwood in the bed of a small, sluggish stream, may back up the water, flooding the valley and forming a lake that extends its boundary as the height of the retaining wall increases with successive deposits of drifting wood.

Among the most remarkable methods of lake formation is the subsidence of a volcanic cone or the destruction of its top by an explosion. Crater Lake, in Oregon, 6,239 feet above sea level, 2,000 feet deep, with precipitous walls extending from 900 to 2,000 feet above the water, and with no known outlet, was caused by subsidence in the volcano. A subsidence caused or accompanied by an earthquake in the "Sunk Country" of the Mississippi Valley has within a little over a century left a lake to proclaim to future generations the severity of the earth's tremors. Lava, bursting from the earth's interior through a volcano or some other vent, and intercepting the waters of rivers by flowing across their valleys, has turned such valleys into lakes. Also irregularities in the surface of lava flows have furnished lake basins for the accumulation of surface waters.

Numerous as are the lakes and ponds produced by these and other methods, all other kinds are few compared with the thousands that owe their origin in one way or another to the action of glacial ice (Figs. 65, 66, 67, 73). Wherever glaciers have held their sway, whether those of the mountainous regions that sent their icy tongues from snow-clad summits down radiating valleys, or the great ice-sheets that crept from their centers of accumulation in the long ago and spread over large portions of Europe, Asia and America, lakes abound, of infinite variety in size and shape. They lend to the landscape a charm so characteristic that a map of the most thickly lake-studded regions of America is approximately coincident with a map of the glaciated areas. Many of the glacial lakes, especially those so abundant in Minnesota and Wisconsin, occupy natural depressions resulting from irregularities in the thickness of the ground moraine. This should be expected, as it cannot be supposed that the amount of material carried and deposited by the ice could be equal in all portions of the great ice-sheets. It is likely that some such depressions have been caused by the melting of large masses of ice that had become embedded in the moraines or in the water-laid deposits near the ends of glaciers. Just such ice blocks are actually found in the terminal moraines of existing glaciers. Some of our most beautiful lakes are retained by terminal moraines constructed at the lower ends of glaciers. These moraines are sometimes, especially in mountainous regions where debris is plentiful and building consequently rapid, so distinctly outlined and of such regularity as to resemble the works of man (Fig. 65). Though it has been vigorously disputed, there is abundant evidence that glaciers have actually scooped out basins in solid rock (Fig. 66). In valleys formerly occupied by mountain glaciers, it is usual to find a series of lakes, some of which are rock basins, some morainal, representing rest periods in the retreat of the glaciers, and some combine both features.

Whatever the origin of a lake, there are processes laboring perpetually for its destruction. In the first place, there is a constant struggle for existence against atmospheric influences at work drawing water from its surface by evaporation. In a dry region, where loss by evaporation exceeds the amount received from streams, springs and direct precipitation, the lake must slowly shrink until nothing but the empty lake-bed is left to tell the tale. Such fossil lake-beds are not uncommon in some portions of the world. They are usually occupied by a little shallow water for a short time after a rainy season. Lakes dying by this process have no direct outlets and therefore fluctuate with every climatic change, swelling with each period of heavy precipitation and shrinking with each period of minimum precipitation. Thus Great Salt Lake has been subject to fluctuations of considerable dimensions since the settlement of Caucasians upon its shore, to say nothing of the enormous oscillations of its parent, Lake Bonneville, which have left their impress upon the geology and scenery of the entire region. The area of Salt Lake increased 420 square miles from 1850 to 1869. Since 1875 constant records have been kept of its annual fluctuations, as well as of the changes due to longer cycles of maximum and minimum precipitation. Ancient Lakes Lahonton and Bonneville each had at least two maximum periods, perhaps with complete desiccation between. Lahonton apparently never rose to a high enough level to find an outlet, so probably remained saline or brackish at its highest stage. Bonneville overflowed its rim, established a temporary outlet and was freshened by replenishment until the water again fell below the level of the outlet, leaving numerous fresh-water mollusk shells in the lacustrine deposits of the terraces. This tells the story of slight changes in climate. In a moist country, where precipitation and inflow exceed the loss by evaporation and percolation, obviously a completely enclosed lake cannot long exist. Sooner or later the accumulating water must reach the lowest point in the rim and establish an outlet, which operates as a safety valve to carry off the surplus and maintain a tolerably constant level. Then the deepening of the outlet by erosion must begin to drain off the water and slowly work the destruction of the lake. The constant effort of running water is to establish complete drainage by cutting down obstructions and filling low places, thus to reduce all land surfaces to gentle and uniform slopes from the highest points to the sea. Where the confining embankment is of porous material, such as gravel, the water may escape by percolation without overflowing or cutting an outlet.

At its very birth the lake, whether it be with or without an outlet, is subject to the attack of another process, laboring incessantly, day and night, in the destruction of the basin. Each tributary stream pours its load of sand and mud into the lake, building its delta of coarser material farther and farther out from the original shore. The finer material is carried by the feeble currents out into deeper water to be deposited upon the bottom. Thus the lake is reduced in both area and depth. Every rill does its share toward filling the reservoir into which it discharges its water gathered from the surrounding hills. Every wave dashing upon the shore loosens soil or grains of sand, which the currents bear away for use in the construction of bars, spits and shoals. So the filling goes on, sometimes so rapidly as to be plainly discernible from month to month, sometimes so slowly as to be scarcely noticeable in the course of years. However slow the process, it is exceedingly sure. The building of a delta may work great changes in the outlines of the lake, as well as simply reducing its area. Two rivers may even cut a lake in two by constructing deltas from opposite shores until they almost meet. Vegetation, too, plays an important part in the filling of lakes. This is especially noticeable in small, shallow lakes. Sedges, peat, and other marsh plants in the edge of the water catch and hold the sediments along the shore, thus building the shore slowly out into the lake (Fig. 67). This continues until the strip becomes dry, grassy land, and, if the lake be shallow enough, the filling may progress from all sides until it is completely choked and destroyed. So it has been said that the "customary appearance of a dead lake is that of a grassy flat where peat has taken the place of water." In places the vegetation first forms hummocks, the spaces between being filled in later. In other places the made-ground takes the form of a rather uniform vertical wall, especially in shallow lakes at high altitudes or high latitudes, which freeze to the bottom in cold weather, the push of the ice keeping up the vertical shore.

It is believed that some of the marls forming on the bottoms of lakes, thus contributing to their extinction, are of animal origin. Hence we have a mingling of botanical, zoological and physical causes all joining in the final result. Many of the small "parks" adding so much to the beauty of the higher Rocky Mountains, furnishing pastures, fields and residence sites amid rugged rocks, and many of the flat, grassy meadows of the glaciated areas of our Northern States, are the filled beds of lakes that once glittered in the sunlight and mirrored their banks in liquid depths. By understanding the various processes engaged in the production and destruction of these fossil lakes, one may to some extent reproduce in the mind's eye the scenery of the past, and greatly enjoy the retrospective view. So to the student of Nature the lake is an object of interest not only because of its present beauty, but also because of its history and its future possibilities.

Lakes differ no more in their origin and causes of destruction than in the character of the waters they contain. The salinity of lakes is of all degrees. No sharply drawn line separates them in this respect. Between the bitter, dense, concentrated waters of Great Salt Lake, the Dead Sea or the ocean, on one hand, and the fresh, sweet waters of a mountain lake in a granitic region, on the other hand, may be found lake waters of every degree of freshness. The cause is easy to find, when we consider how much lakes differ in the conditions that govern their existence, the soils and rocks through which their tributaries flow, the relation of inflow to outflow, and so on. At first thought the insignificant percentage of salts in solution in river water may seem of little consequence, yet in the aggregate the amount is so vast as to assume great importance as the centuries roll by. Lakes with outlets are kept fresh by the fact that the salts are carried away by the outflowing water. In completely enclosed lakes of arid regions, where the loss of water is by evaporation, the salts are left in the lake, forming a concentrated solution. Therefore we may think of saline lakes or the ocean as concentrated river water. The concentration may continue until the water becomes completely saturated and can hold no more. Then the salts will be deposited in regular order. So changes in the salinity of the water may sometimes be read from the deposits, and the order of their superposition, at the bottom of a lake or in the fossil bed of an extinct lake.

Passing now to their outlines, we find that, great as is the diversity in the origin of lakes and the means of their destruction, there are limits to those things, but the variation of outline and shore detail is boundless. Their infinite diversity, vertical as well as horizontal, depends very largely upon forces engaged in their formation and destruction, the character of the rocks and soils surrounding them, and the progress made in their development and destruction. Whatever the original form may be, it cannot long remain the same. While waves are engaged in cutting away the land at one point, waves, streams and shore currents are engaged in building it out at another, thus ever changing its outlines. On the west side of Lake Michigan the cliffs are said to be receding at an average rate of five feet per annum, the maximum rate being sixteen feet. At Cleveland the average rate of recession was six feet per annum for forty years, according to Russell.

Lake scenery is essentially a matter of shore lines, cliffs, headlands, beaches, bars, spits, islands, and surrounding vegetation, all bearing definite relation to each other, and to the currents, waves and winds. So definite are some of these relations, so certain the laws governing the production of some of these features, that to the trained eye the shore is often an open book, telling in unmistakable terms the story of its development, though often more complicated and sometimes perhaps beyond comprehension.

Shores have life histories, as rivers, mountains and other topographic features have—periods of youth, maturity and old age. The period of development from infancy to old age may be termed a cycle, whether it be the few hours required by a roadside pool cradled in soft, yielding material, or the ages required by an inland sea, expending its energies upon granite. Infancy is evidenced by irregularity, sharp curves, numerous small bays and headlands and general lack of adjustment to the movements of the water. The formation of cliffs, spits, barriers and other shore features is the result of the constant efforts of current and wave to establish harmony· Erosion at first proceeds rapidly, cutting away sharp points and filling minor identations in the shore line. The destruction of irregularities gives broader sweep to the currents, eliminates eddies and makes possible the working out of greater changes by the forces of destruction and construction. As the beach approaches maturity it assumes a different appearance, characterized by regularity, without sharp headlands and re-entrant angles, so that nowhere does either cutting or filling proceed so rapidly. In other words, the lake now begins to retire from active operations and to use the beaches made in its more youthful days, as someone has expressed it. So it passes on to old age with its work well done.

As river terraces often enable one to read a portion of the past history of the stream, so lake terraces may enable one to ascertain past fluctuations in the water level. The making of such terraces is not possible, while the water level is uniformly and steadily rising or falling, except where there are alternating hard and soft horizontal strata. It occurs when the water level remains tolerably constant for a period. The length of the period required depends upon the character of the shore materials, the force of the waves and other conditions. The tiny wavelets on a roadside puddle may in a few hours construct a miniature terrace in the yielding materials of its embankment. It may require centuries for the ocean's breakers to carve a respectable terrace in a hard sandstone or granitic cliff. The principle in both cases is the same. From this it follows that each stationary period of long enough duration leaves its record on the shore. From the method and order of their occurrence one may even ascertain which terraces followed a rise in water level and which followed a period of receding water. An exhaustive study of the terraces and bottom deposits of ancient Lake Bonneville has furnished a wonderful account of its fluctuations. At one time it reached a depth of hundreds of feet. Its ancient terraces in the Salt Lake Valley, when the sun's rays strike them at the proper angle to bring them into strong relief, give to the scenery a very impressive aspect. Such a series of terraces is seldom formed except in the vicinity of a land-locked lake, whose depth varies from time to time as a result of cycles of increased and decreased precipitation or temperature.

Part of the variation in lakeshore and seashore scenery is due to the difference in the abruptness of the shores. This depends partly upon the character of the material and partly upon the effects of frost, the chemical action of the atmosphere and other causes. Consequently the influence of geological conditions and processes upon such scenery is often very evident. In regions of great fluctuations in temperature or rapid subaerial decay, or where the embanking materials are soft and yielding, the top of the cliff is likely to recede more rapidly than the waves can bear away the detritus from the base. In such a case the shore soon becomes a gentle slope to the very water's edge, and indeed far out beneath the water, but if these conditions are reversed a cliff may long remain nearly vertical or even somewhat overhanging. The character of the rocks and soils and the activity of frost and other agencies also determine the rapidity with which waste materials may accumulate for the construction of barrier beaches, spits and other shore features.

No less important than the destructive inroads of wave and current upon the shore, is their work of construction. As the waves agitate the sediments alongshore, even the most feeble currents may perform effective service in carrying them forward and depositing them at other points. Currents passing abrupt headlands are unable to make the turn quickly enough to hug the shore closely, so they carry the material outward and build bars or spits away from shore. Once established, the bar forms an embankment along which other sediments travel, constantly adding to its length, until, perchance, it extends to the opposite headland, isolating a lagoon from the main body of water (Fig. 52). Or, meeting other currents, it may be deflected and possibly carried back to the same shore at another point, making a loop. Thus the great variety of sandspits found in shallow waters of lakes and shallow seas are governed by, and consequently help us to understand, the shore currents and winds. Waves, rolling up the beach diagonally, often carry forward portions of the sand and gravel, then, returning at right angle with the beach line, leave the sediments at the advanced position until the next wave gives them another lift on their journey. A great breaker, leaping upon an exposed shelving beach, seems like a thing of life, reaching forward to seize anything in its way. The undertow, sweeping back beneath the advance of the next wave, as though hurrying to hide its plunder, drags with it some portion of the sediments stirred up by its movements. When the angle of the slope has been so reduced that the waves no longer drag down the sands, the process may be reversed. Then the waves build up a barrier beach by piling up sand some distance from the water's edge, thus moving the shore outward and producing a steeper beach, in the perpetual effort to establish harmony between wave and shore. Such a "barrier beach" may enclose a small lakelet.

The shifting of sands by the wind is an element of no small importance in the construction, modification and destruction of lakeshores and lakeshore landscapes. The wind-blown sand may extend out into the lake, thus reducing its size; or it may encroach upon the land, changing the plant societies or even destroying all vegetation for the time being.

From a knowledge of all the principles involved, we may not only be assured that each bit of lakeshore landscape is the result of geological processes, but in many cases may even determine just what processes were involved and what laws contributed to the final result.

"There is beauty in the rolling clouds, and placid shingle
beach,
In feathery snows, and whistling winds, and dun electric
skies:
There is beauty in the rounded woods, dank with heavy
foliage,

In laughing fields, and dinted hills, the valley and its lake:
There is beauty in the gullies, beauty on the cliffs, beauty in the sun and shade,
In rocks and rivers, seas and plains—the earth is drowned in beauty."

TUPPER.

The Ocean

"Roll on, thou deep and dark blue Ocean—roll!
Ten thousand fleets sweep over thee in vain;
Man marks the earth with ruin—his control
Stops with the shore."

Byron.

THE most stupendous fact on the face of the earth is the ocean. Its importance in relation to the scenery of the world can scarcely be overestimated. It is a continuous body of water covering nearly three-fourths of all the surface of the earth. There is nothing completely separating the Pacific from the Atlantic, Indian, Antarctic or Arctic Oceans. They are all governed by the same laws. They surround and separate the land masses — the continents and islands. The average altitude of the land above the sea is only 2,300 feet, while the average depth of the ocean is about 12,000 feet. Yet the altitude of the highest point of land, nearly 30,000 feet above sea level, approximately equals the deepest ocean trench yet sounded.

The coast lines of all the continents and oceanic islands, with their innumerable bays, straits and inlets, aggregate many thousands of miles. Upon almost every mile of these coasts the waves are beating incessantly, and the tides are ebbing and flowing, as they have been through all the past ages. Everywhere on rugged coasts the surf is breaking with more or less force (Figs. 42, 43, 68, 69), tearing and wearing away the rocks and depositing the debris elsewhere in the construction of new formations. On low-lying coasts, or those of more gentle contours, the waves are continually shifting the sands, building here and cutting there one season, cutting here and building there the next. At times the inroads made by a single storm transforms the landscape over many acres. At times the storms and continuous action of the waves of a single season encroach upon the land for many yards, or add acres of new ground to the dry land, thus radically affecting the coastal scenery. As the building-up process is less noticeable, in watching the destructive onslaughts of the waves, the impression is that the ocean is seeking to tear the continents to pieces. Artists are prone to picture the sea in its more boisterous moods, with ships tossing on the billows. Poets write of the irresistible power of the ocean, driven before the winter's storm.

> "Where shall he find, O Waves!
> A load your Atlas shoulders cannot lift?"
> EMERSON.

Standing upon a rocky point where the wind has wide sweep, during or immediately after a severe storm, one may well be amazed at the force of the waves, as they surge forward, dashing against the rocks, scattering their spray far and wide, each with a force of one or several tons to the square foot. The blows, like those of a giant hammer, repeated momentarily, hour after hour, several thousand shocks per day, loosen and break off jagged corners of rock weakened by frost and other

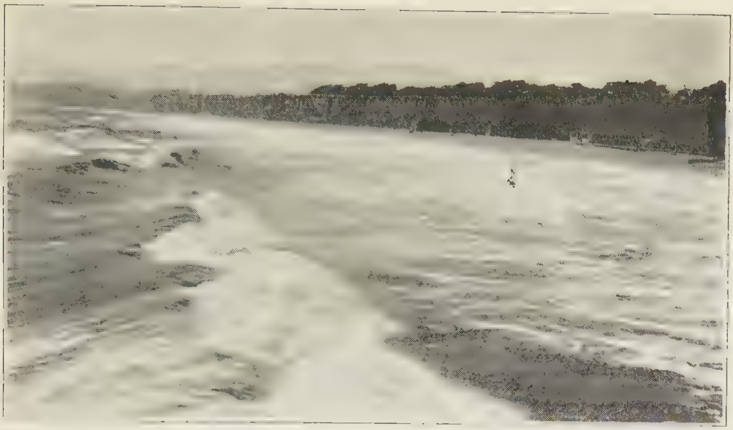

Fig. 69 — Sea-cliff caused by horizontal wave erosion.

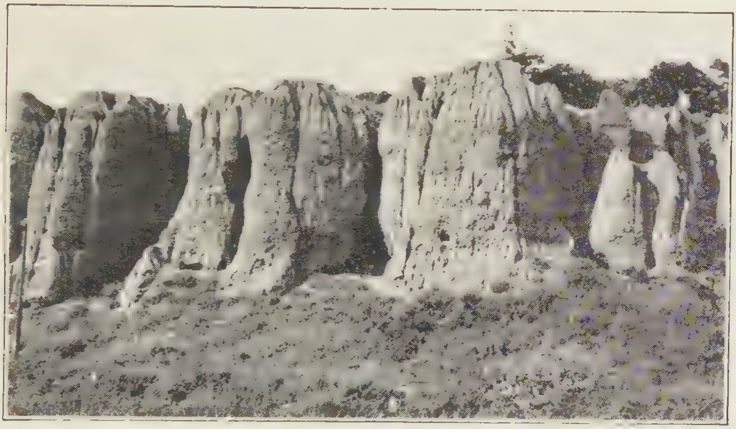

Fig. 70 — Same sea-cliff showing dissection by vertical storm-water erosion.

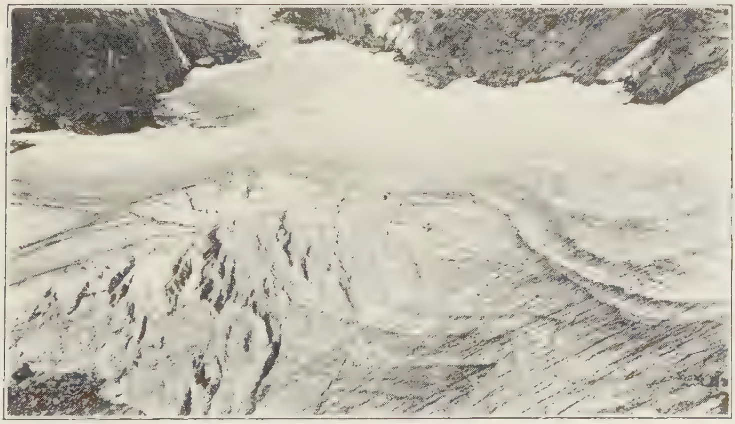

Fig. 71 — Arapahoe Glacier, Colorado, showing main crevasse system in lower left-hand corner.

agencies, thus exposing new surfaces upon which erosion may begin its work. Isolated points upon which the waves may exert their most effective force are separated by the cutting away of surrounding portions of the rocky wall. This requires a more substantial tool than clear water. Such a tool is found in the gravel at the foot of the cliff. As a wave rolls in, it picks up a portion of the loose sand and gravel and hurls it against the solid rock, grinding up the loose fragments broken off by other means and carving away the softer and more accessible portions of the cliff. As the work progresses, the breaking up of the cliff constantly replenishes the supply of gravel. This leads to the assertion that the rocks furnish the tools with which they are being destroyed. With this principle in mind, one may readily understand how a rocky headland may stand for ages almost undisturbed by the action of the surf. The effective force of the waves extends but a few feet or fathoms below the surface. If the rocks descend abruptly to considerable depth without a shelf or ledge upon which gravel may lodge, the waves can find no tool with which to work and therefore make but little headway in their bombardment. Even where the cliff does not descend abruptly to deep water, the waves may be deprived of cutting power by offshore or alongshore currents that bear away the debris as fast as it is broken from the rocky wall, making thus possible a sea cliff without talus. Waves are not alone in the work of shore erosion. Erosion by sediment-bearing currents produced by the winds or otherwise, as well as aeolian erosion, may aid greatly in altering the appearance of the seashore.

In many respects the work of the waves and streams is alike, as in the difference in erosive power between clear and sand-laden water. In other ways stream and wave erosion differ radically. Speaking in a general way, waves cut horizontally into the land, while streams cut vertically. The one process has not inaptly been likened to the work of a horizontal saw, the other to the work of a vertical saw. Magnificent examples of the difference may be found along the seashore, where the waves have cut into the land horizontally, leaving a steep cliff, which has then been dissected by the vertical erosion of temporary rivulets born of storms or flying spray (Figs. 69, 70). It must not be forgotten, though, that under many circumstances streams cut almost horizontally into embankments, leaving steep cliffs as the result of their work, and also widen their valleys and produce peneplains after they have cut downward as far as their grades permit; but generally the two kinds of terraces may be readily distinguished by other phenomena.

The ocean is essentially a great saline lake. Hence for the greater part the principles applicable to lakeshores are in full operation on a grander scale along the seashore, Nature's forces seeking ever to destroy jutting points and sharp re-entrant angles, thereby changing rugged outlines to curves of beauty. However, the seashore problems are greatly complicated by the ebb and flow of tides that never for a single hour leave the water at the same level.

The rise and fall of the tide is accomplished with such regularity and precision that its hours of ebb and flow may be calculated for years in advance, from the same sort of data that makes possible the accurate calculation of the phases of the moon. So definite are the laws governing this phenomena that the ocean's tides afford a symbol of things eternal and unchangeable.

> "And in thy mathematic ebb and flow,
> Giving hint of that which changes not."
> EMERSON.

Twice daily, year in and year out, as certainly as the sun rises and sets, the seaside landscapes are transformed as the tide flows in, covering rocks and beaches, then out, leaving the rocks and tide-flats exposed to the atmosphere.

As tremendous a factor as the thousands of miles of diverse and changing seashores are in the scenic aggregate of the world, it is perhaps exceeded by the indirect effect of the vast expanse of water through its influence upon climate. A landscape without vegetation, whether by the sea or far inland, is a dreary waste. Two controlling factors in the vegetative cover of any locality are temperature and moisture. Both are the result of the distribution of the larger bodies of land and water and the relation of the ocean to mountains, plateaus, plains and valleys. A rainless earth would be a plantless earth. All the rain that falls upon all the land surfaces is derived directly or indirectly from the ocean. Evaporation is proceeding upon almost all of the ocean's surface, about five-seventh's of the whole surface of the earth. To this is added the vapor from rivers, ponds and moist land, which has previously come from the ocean. The invisible vapor, leaving the minerals behind, rises to higher strata of the air and is wafted over the land.

> "The sea tosses and foams to find
> Its way up to the cloud and wind."
> EMERSON.

Over islands and continents the moisture-laden air currents come into contact with colder currents or mountain ranges, the vapor is cooled, condensed, and falls in the form of rain and snow. This irrigates Nature's gardens and enables trees and flowers to flourish. The surplus runs off in rills and rivers, replenishes the ponds and lakes that brighten the landscapes, and ultimately much of it finds its way back to the ocean.

The salinity of the ocean's waters directly affects seashore views through its influence upon vegetation. Certain plants are unable to thrive close to the sea, where salt spray dashes over from the beating of the surf. Other plants are especially adapted to life in a salt marsh, or reach their greatest perfection under the salt spray. Great beds of marine algae, or kelp, rising and falling with the waves, add variety to the scenery. Sponges, corals and other beautiful marine animals, mingling with waving marine plants in the clear, warm water of the tropics and sub-tropics, form the weird and delightful "marine gardens" viewed through glass-bottomed boats at seaside resorts.

In 1,000 parts of sea water, about thirty-five parts consist of minerals in solution, more than three-quarters of which is common salt. All this is derived from streams flowing into the ocean. It is said that the Thames annually carries to the sea 600,000 tons of minerals in solution, the Mississippi 113,000,000 tons, the Nile 17,000,000 tons, the Croton 1,500,000 tons, the Hudson 66,000 tons and other streams in proportion, besides the great quantities of sediments in suspension. The total amount of minerals in solution annually carried to the sea is estimated at 5,000,000,000 tons for the whole earth. Though the aggregate is very great, it is only a small fraction of one per cent of the volume of water flowing in the rivers. The great volume of water carrying small percentages of salts pouring into the ocean, is slowly concentrated by evaporation from the surface, part of the water passing into the atmosphere as vapor, leaving the soluble minerals in the ocean water, thus keeping it forever saline and very gradually increasing its salinity.

So the ocean, giving to us its thousands of miles of coastal scenery, providing rain and snow and in part controlling temperature, thus affecting vegetation, may be considered one of the most important geological agencies in the making of landscapes, and one of the best examples in the world of power in the sculpturing of the earth's surface.

"The Ocean old,
Centuries old,
Strong as youth and as uncontrolled,
Paces restless to and fro,
Up and down the sands of gold.
His beating heart is not at rest;

And far and wide,
With ceaseless flow,
His beard of snow
Heaves with the heaving of his breast."
LONGFELLOW.

The Glacier

"The beautiful is as useful as the useful."
VICTOR HUGO.

GLACIERS and glacial topography are the dominant elements in the landscapes of some portions of the world. This is obvious in the Antarctic region, where little is to be seen except the vast sheet of ice, with its vertical front along those portions of the coast where the ice extends out into the sea. It is nearly as obvious to the glacialist amid the cirques and moraines of high mountain ranges, the kames and erratic boulders of Wisconsin, and the eskers of Scandinavia.

A glacier is a slowly moving body of ice — not an avalanche — not sliding down a slope as a solid body of rock might slide, but flowing in a manner somewhat analogous to the movement of a stream of water. The motion, slower in winter and more rapid in summer, may be from a few feet per annum in a small glacier to several feet daily in a large one. In the life history of a glacier there is no sharp dividing line between the mature glacier and the snow-bank in which it has its birth or the one in which it dies. At no point in its career may one say that at this precise moment it becomes a glacier, or at this moment the glacier ceases to be. Wherever the winter's accumulation of snow annually exceeds the summer's dissipation by melting and evaporation, a glacier must find its origin. Be the surplus each season ever so small, if long enough continued its accumulation will result in a deposit of such thickness that it forms ice, and under pressure of its own weight, it will begin to flow outward or downward from the area of accumulation, not as a liquid or viscous substance, and not by sliding, but as a solid mass, by recrystallization. Some movement may be detected in the well consolidated snow — in the névé, which has not yet acquired the characteristics of true glacial ice. As the weight continues to increase, pressure and movement increases, and slowly the snow is transformed into glacial ice. Finally, through accelerated movement during the summer, perhaps the ice breaks away from the névé, along a line known as the bergschrund (Fig. 72). With the bergschrund established and the ice tongue extending well below, it is a glacier. The bergschrund may consist of a single crevasse along a well-defined line, or a number of more or less irregular crevasses extending over a wide zone. It is to be distinguished from the ordinary crevasses (Fig. 71), which form wherever tension occurs in the ice, as from an abrupt increase in the bed of the glacier, or from any other cause. Sometimes covered by a thin sheet of ice and snow, both the bergschrund and ordinary crevasses are very dangerous. The body of a man who lost his life in a Swiss glacier is said to have been deposited on the terminal moraine ten years later. Hallet Glacier in Colorado was brought to the attention of glacialists by a man breaking through into a crevasse. A mountain sheep that had evidently met its fate by falling into a crevasse on Arapahoe Glacier was carried slowly downward until its carcass was exposed by the melting of the ice at the foot of the glacier.

The ice moves away from the accumulation field until it reaches a region where the annual loss is greater than can be replenished by the accessions at the head of the glacier. In case of mountain glaciers the movement is down the slopes and valleys, and in a general way temperature increases with decreased altitude. In case of a continental glacier it is a radiating movement in all directions from a center of accumulation. The great continental glaciers that in Pleistocene time covered large portions of North America and Europe did not form in the Arctic region and simply move southward, as is so commonly supposed, but radiated from several centers, none of which, perhaps, were in the neighborhood of the North Pole.

Three principal types of glacier may be recognized. Those of the alpine (or mountain) type form on high mountains, where the winter snowfall is heavy and the summer melting not excessive, and extend their icy tongues down the slopes, gulches and valleys. Such are the glaciers of the Alps, Himalayas, Rockies, Andes, and other great mountain ranges, including the mountains of Scandinavia and New Zealand, and the higher peaks of tropical Africa. Here again we see the geologic and scenic influence of the wind, for most mountain glaciers owe their existence to drifted snow. Their positions are determined by the relation of the topography to the prevailing direction of the winds. Mountain glaciers, leaving their narrow valleys, may expand and unite upon the plains to form a piedmont glacier. This is well exemplified by the Malaspina Glacier, in Alaska, with an area of 1,500 square miles and a thickness of from 1,000 to 1,500 feet, fed by numerous alpine ice-streams from Mount St. Elias and neighboring peaks. The continental type, as the name indicates, includes ice-bodies of vast extent, such as the great sheets that cover Greenland and the Antarctic continent and those that once spread over the northern portions of Europe and North America. Arctic and Antarctic glaciers extend out to sea into water of sufficient depth to float the ice. Large masses, breaking away from the ice front, float away as icebergs, five-sevenths of their bulk hidden beneath the surface of the water. They form fleeting but highly interesting features of the oceanic scenery in the North Atlantic in spring and summer, endangering shipping as they float southward until they melt in the warmer atmosphere and waters of lower latitudes.

While the large glaciers extended over so much of the northern hemisphere, many thousands of mountain glaciers, of which remnants still exist in many localities, occupied the higher mountain valleys. Several times did the glaciers of both types advance and retreat, leaving the history of their oscillations recorded in the moraines deposited by the ice, and in other glacial phenomena. The glaciers of the Swiss Alps are those best known to the general public, though by no means the largest or most important. In the mountains of western North America, from Colorado and California to Alaska, are

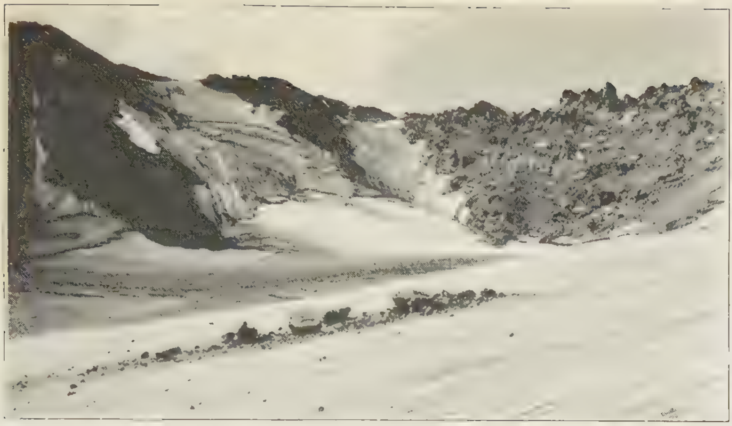

FIG. 72 — Arapahoe Glacier, showing the bergschrund (the great semi-circular crevasse near the top), bearing giant rocks on its back, moving at the rate of 27½ feet per annum.

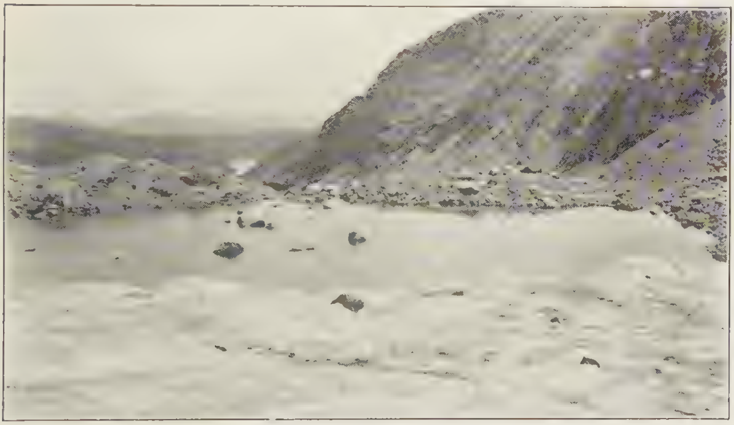

FIG. 73 — Arapahoe Glacier, showing present terminal moraine and lake retained thereby, indicating recent retreat of the ice front.

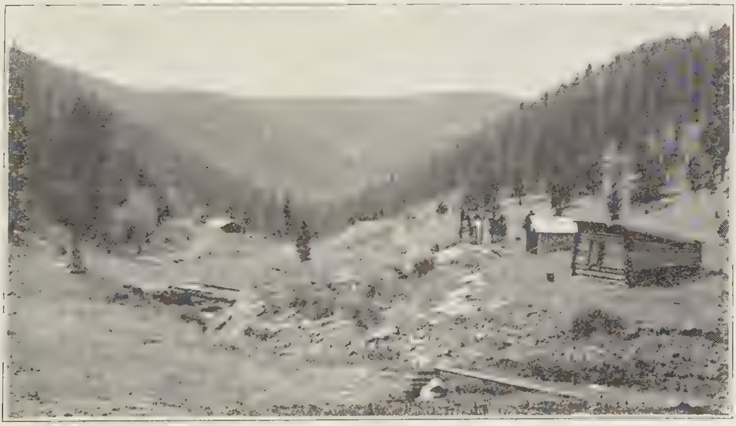

FIG. 74 — A V-shaped stream-cut valley.

many hundreds of glaciers larger than the average of the Swiss glaciers. Some of the more northern ones are five times, and some in the Himalayas three times as long as the longest in Switzerland. A map of Mount Rainier, in Washington, with its several glacial arms radiating from the summit down the valleys, may remind one of a giant starfish or octopus.

The ice usually bears upon its surface and firmly embedded within, boulders, sand and gravel (Fig. 72). These it deposits along its bed (ground moraine), or along the margins (marginal moraine), or at and below the junction of two glaciers (medial moraine), or at the terminus (terminal moraine) (Figs. 65, 73). It grinds and polishes the rocks over which it moves, the water flowing away from the lower end of the ice being often milk-white from the sediment ("rock flour") which it contains. The smooth, rounded hills, often striated and highly polished, over which a glacier has passed—*roches moutonnées* (Fig. 66)—remain for centuries after the retreat of the ice-stream, partly or wholly devoid of vegetation, to tell of the grinding power of moving ice. The V-shaped valleys formed by stream erosion (Fig. 74), are transformed into U-shaped valleys by the glacier (Fig. 75). It does not make the valley, perhaps does not even deepen it, but modifies one already in existence. A stream of water cuts in a narrow line, while the valley is widened above by lateral subaerial erosion. When the valley fills with ice subaerial erosion of its hidden sides ceases. As the pressure is greatest on the sides of the valley toward the bottom, glacial erosion is there most active, widening the valley more rapidly at the bottom than toward the top. It is not likely that the clear ice itself does much of the cutting. It merely furnishes the weight, power and movement, while gravel and boulders held firmly in the bottom and sides of the ice are the tools with which the glacier cuts, digs, grinds and scours the rocks over which it moves, cutting off angles and reducing resisting hills, while it drops some of its load into the hollows and fills up some of the depressions with detritus gathered on its journey. The glacier is also able to scoop out shallow basins in softer rocks, and thus form rock basin lakes (Fig. 66), which often mingle with morainal lakes in a mountainous region. The melting of the ice leaves massive boulders in its former pathway, sometimes one perched upon another (Fig. 76).

Almost all glaciers everywhere in the world are now in retreat. In many cases their recession has been watched and measured for years. While accumulation and loss are evenly balanced, the front of a glacier remains approximately stationary, being constantly replenished by movement from the center of accumulation. As the climate proceeds in cycles of maximum and minimum precipitation and temperature, glaciers remain fairly stationary for a time, then shrink or expand. During the stationary periods terminal moraines (Figs. 65, 73) are formed of the boulders, sand, gravel and mud dropped where the steadily on-coming ice melts at the foot of the glacier. When shrinkage occurs, a new terminal moraine is built at the next stationary period. When the glacier expands, it may extend out over the old moraine and

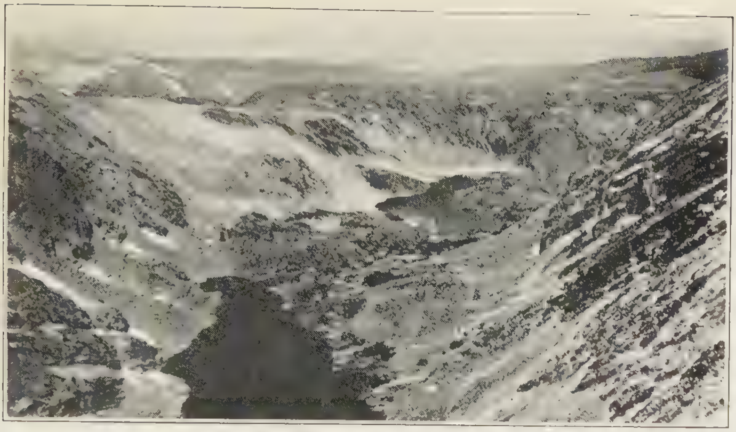

FIG. 75 — Valley modified to U-shape by glacial erosion, containing glacial lakes.

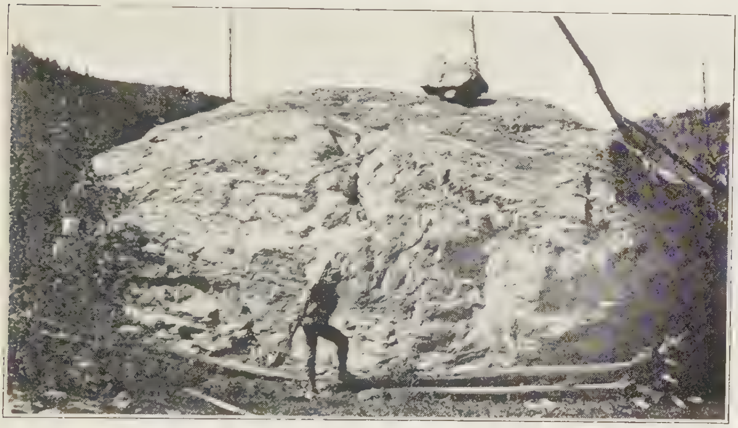

FIG. 76 — A glacial boulder, with a "perched" boulder on top.

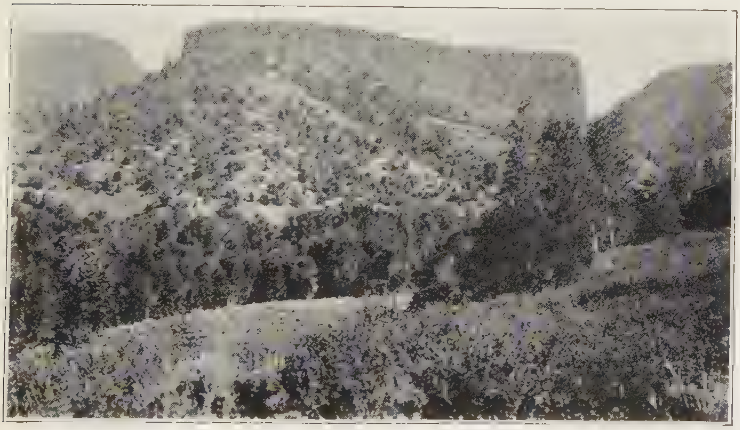

FIG. 77 — A mountain caused by dissection of a thick sheet of lava by stream erosion, the vertical wall being due to vertical columnar structure of the lava.

build another in front of it. The shape of the terminus may change, resulting in building one moraine diagonally across an older on. The ground moraine left by the ice along the bed of the glacier also differs greatly in thickness, as the amount of material conveyed by some portions of the ice is greater than that conveyed by other portions. The quantity of material carried differs not only in various parts of the ice, but also at different times. This is beautifully shown in the photograph of Arapahoe Glacier (Fig. 72). Hundreds of tons of rock in great blocks, broken from a cliff far up the glacier many years ago, rest upon the ice, and are being carried onward at the rate of about twenty-seven feet per annum, while other portions of the surface are comparatively free from debris. As a result of these variations in quantity of material available and in the position and shape of the terminus, neither the terminal moraine nor the ground moraine presents to the eye hills and valleys in orderly systems, such as are produced by aqueous erosion and deposition. The elevations are often thrown together in inextricable confusion, unless modified and masked by subsequent events. Examples of both evenly and unevenly laid terminal moraines built by the same glacier at different periods may be seen in figures 65 and 73. Myriads of glacial lakes nestle in the depressions of ground moraines and behind terminal moraines (Figs. 64, 65, 66, 67, 73).

Another feature of glacial topography, especially striking in heavily glaciated mountain regions, is the occurrence of numerous amphitheaters or "cirques."

Many geologists believe they owe their origin to the plucking action of the ice at the bottoms of bergschrunds, assisted by the water that drops in from above. This theory has been vigorously attacked, especially in Europe, but it is supported by some very substantial evidence. Whatever the explanation, the association of such phenomena with other glacial phenomena indicates that in some way they are the result of the action of glaciers.

Besides the modification of valleys, the formation of cirques and lakes, the reduction and alteration of hills, the production of ice-bergs, and the building of moraines, glaciers have exercised a notable influence upon scenery in many regions, by radically changing drainage systems, the ice or moraines having filled valleys and stopped the flow of water therein until new channels were established. Then, in addition to all the varied effects of ancient glacial erosion and deposition, the existing glaciers themselves are among the most important features of the landscapes where they occur, to say nothing of the numerous lakes left in their retreat. So all the cirques, moraines, U-shaped valleys, hanging valleys, lakes, *roches moutonnées,* polished and striated rocks, drumlins, kames and eskers combine to form characteristic scenery quite different from that of non-glaciated regions. By understanding the work of existing glaciers, one may understand to some extent how some of the present landscapes came into existence. One may also mentally replace the ancient ice, and, with very little strain upon the imagination, restore the scenery of the past, even determining where crevasses and bergschrunds must have developed, and with the "mind's eye" view the changing landscapes at various stages of the advance and retreat of the ice.

The Mountain

"Thou who wouldst see the lovely and the wild
Mingled in harmony on Nature's face,
Ascend our mountains. Let thy foot
Fail not with weariness, for on their tops
The beauty and majesty of the earth,
Spread wide beneath, shall make thee to forget
The steep and toilsome way."

BRYANT.

IF the ocean, with its vast expanse, is the most stupendous fact on the surface of the earth, the great mountain ranges are the most impressive. The ocean, stretching away with its general level unbroken save by the rolling billows or an occasional ship, meets the horizon but a few miles distant. The tallest masts of ships may not be seen many miles away. Mountains, on the other hand, may in some cases be seen at a glance stretching for a hundred miles in every direction or breaking the sky-line thousands of feet above the observer.

"Hills peep o'er hills, and Alps on Alps arise!"

POPE.

As ridge after ridge, range after range and mountain after mountain recede in the distance, the blue haze deepens, until finally it blots out the peaks beyond the vision.

" 'Tis distance lends enchantment to the view
And robes the mountain in its azure hue."

CAMPBELL.

For a beautiful landscape one turns to the quiet meadow, the meandering brook, a forest vista or a bit of tree-clad lakeside. For a majestic view one seeks the seaside, with the ocean spreading away into the distance, its surging waves and the ceaseless flow of its tides speaking of relentless and eternal power. For bolder scenery, with greater variety of form, one visits the older and more rounded mountains, as of New England, Eastern Canada, Wales and Scotland, whose abrupt lines have been planed off by the erosion of ages, but whose heights still gently rise far above their surroundings. For grand, lofty, inspiring scenery one goes to the younger mountain ranges of the earth, where "wildness of youth has not yet been tempered by the mellowness of age" (LeConte), as the Himalayas, Andes, Alps and portions of the Rockies (Fig. 1), whose rugged, rocky pinnacles and deep, narrow canyons remind one of their youthfulness and the vigor of the forces engaged in their production, modification and ultimate destruction.

As there is no sharp line of division between long and short, big and little, rills and rivers, or ponds and lakes, so no sharp line separates hills from mountains. An elevation that seems but a tiny hill in the more rugged portions of the Rocky Mountains would be a creditable mountain if transported to the plains of Kansas or the lowlands of Holland.

Like rivers and lakes, mountains have life histories. Some are of comparatively recent origin. Some have reached maturity or old age. Some have passed away, leaving their planed-off stumps, upon which new mountains have been builded. Such stumps are the "bones of extinct mountains," as LeConte has expressed it, from which we may mentally reconstruct in part the mountain scenery of the remote past. Thus southern New England, now only a hilly country, "once presented the aspect of a mountainous region with lofty mountain ranges running north and south through it" (Pirsson).

Mountains and hills vary in their origin and in other ways, and so vary in their history. Some are eruptive, resulting from the exclusion of lavas (volcanoes). Some are the result of the intrusion of molten magmas into other formations, the latter being afterwards eroded away from the lava after it has cooled and hardened, leaving it standing out as a hill or mountain (Figs. 47, 77, 94). Some are the result of direct uplift above the surrounding region by lateral squeezing. Others are eroded from broad, level plateaus raised above the surrounding region sufficiently to provide rapid drainage. Some are the result of simple folding or the tilting of blocks produced by parallel faults. Some are the combined result of one or more of these and other causes. Adding to these things the variation in the character of materials, the varying angle to which strata are tilted, the effects of these variations upon erosion, and the effect of soils, slopes and climatic conditions upon vegetation, one may comprehend why mountain scenery presents such infinite variety.

The Front Range of the southern Rockies has a "granitic core," elevated to an altitude of over 14,000 feet above sea level at the highest points, dragging up to a high angle the once level sedimentary rocks along its flanks. Some idea of the enormity of the differential movement and subsequent erosion may be obtained from the fact that strata that once rested 10,000 feet below the sea level and was covered by that amount of marine strata, are now found from 8,000 to 12,000 feet above sea level, tilted, folded and faulted. The granite, exposed by erosion, forms the high peaks of that portion of the Continental Divide — the "backbone of the continent." Much of the topography is that characteristic of massive, homogeneous, unstratified rocks (granite, etc.), but along the eastern foothills it gives way to narrow ridges produced by erosion of stratified rocks of varying resistance, tilted to high angles (Figs. 21, 84, 92).

A correct conception of the southern Rocky Mountains is that of a great granitic plateau, deeply dissected. This dissection, as is true in case of all other mountain systems, is due to stream erosion. Therefore the canyons and divides are quite systematic. One unfamiliar with this fact may see in a mountain range a confused labyrinth of unrelated gorges, and an equally confused jumble of unrelated elevations, but an accurate map would disclose the same orderly arrangement as with a river and its tributaries (Fig 48), since the canyons are the river valleys and the elevations are the divides between the deeply-entrenched streams. It is quite possible to start at the highest point on a mountain system and travel continually down hill to the very base of the mountains, because every slope leads into a canyon and the drainage is ever downward.

The Grand Canyon region in Arizona is a high plateau of mostly horizontal strata. Because of the difference in formations and geological history, its scenic aspect is very different from that of the Front Range in Colorado. Mountains and headlands have been formed by the erosion of deep canyons that partly or wholly isolate portions of the plateau from the general level. Their sides are marked by numerous terraces where harder horizontal rocks alternate with less resistant strata.

The short, narrow, parallel ranges of mountains so common in Utah and Nevada are generally believed to be due largely to the tilting of fault blocks, complicated by folds and much modified by subsequent erosion.

There are reasons for suspecting that even now some mountain ranges are slowly rising, with reference to sea level. The process usually designated as elevation may be merely relative. The depression of the surrounding country or the retirement of the sea into deeper basins produced by the wrinkling of the earth's crust would equally well produce mountains and plateaus. Certain it is that erosion is proceeding rapidly on abrupt peaks, and must reduce their altitude unless the movement that brought them to their present positions continues.

Annually billions of tons of debris from the erosion of rocks and soils are removed from higher portions of the continents and large islands and deposited in the lowlands. In the course of centuries the aggregate change in the distribution of weight assumes tremendous proportions. Rocks are not rigid. Deep beneath the surface, where high temperatures occur, they become molten or more or less plastic, and are subject to a sort of viscous movement. From the tilting caused by such transfers of load, and from lateral compression, stresses and strains result, folds and faults are formed and mountains are built.

A map of the New World shows a series of mountain ranges extending north and south in an almost unbroken line in the western part of the two continents, from Alaska to Patagonia, a distance perhaps of five thousand miles, spreading out in the United States from the Pacific Coast to the eastern foothills of the Rockies. Another series extends along the east coast from Canada to Georgia. The highest peak of the Andes reaches an altitude of 23,000 feet. The highest in Mexico is more than 19,000 feet. In Alaska, Mt. McKinley reaches 20,000 feet. "Its walls offer a barrier to the warm, humid airs of the Pacific, as well as to the icy winds of the Arctic, and the elements thunder around it, making its surface a ceaseless battleground" (Cook). St. Elias, also in Alaska, towers 18,000 feet above the sea. In Colorado alone forty-six peaks rise to more than 14,000 feet, and a great many others to nearly that height, at which snow and ice are formed the year round, and it freezes nearly every night, winter and summer. The limit of trees in the southern Rockies is about 11,500 feet, decreasing to the northward. Turning now to the map of the Old World, we find mountain ranges in Europe and Asia trending easterly and westerly, approximately at right angle with those of the New World. In India are the highest points of land on the surface of the earth, reaching more than 29,000 feet in the Himalayas. A woman of strength, courage and experience is said to have reached an altitude of 23,000 feet on one of those tremendous peaks, and to have camped at 19,000 feet. In Africa peaks rise to 20,000 feet, where the temperature is so low that glaciers continue to exist under the tropical sun. Even on small oceanic islands high mountains occur. Deep sea soundings have revealed the presence of lofty submarine mountains and mountain ranges, in some instances reaching altitudes of 11,000 feet above the floor of the ocean basins without projecting above the surface of the water. To some of these submarine mountains names have been given and placed upon the navigator's charts just as though they were visible to the human eye. Very numerous small ranges of mountains are scattered widely over the earth, grading insensibly down to small hills, which are miniature mountains. So the hills and mountains are the most impressive elements of landscape, and may be said to dominate the scenery of the world as a whole, notwithstanding the vast expanses of plains and valleys and the broad, heaving ocean.

We need not wonder that ancient peoples have deified mountains. Thus we have the sacred mountain of Japan, so well-known through Japanese art and tourists' picture post-cards. So the Mohave and Chemehuevi of Arizona, California and Nevada, have their sacred mountain, whose name has been locally rendered into English as Ghost or Spirit Mountain, though it appears on the maps under the prosaic name of Dead Mountain.

Into the legend of their culture hero in connection with this mountain, the mission Indians have interwoven the story of the Christ. Mountains in various other parts of the world have been deified, as have rivers, rocks and other natural objects.

The pre-Cambrian Laurentian Mountains of Canada are reduced to low hills. The Appalachians are pre-Triassic in their origin, their outlines now rounded, in evidence of their maturity. The Sierra Nevada, in California, are pre-Cretaceous, as shown by the strata involved and upturned along their bases. The southern Rockies are post-Cretaceous, their rise having been accompanied by the final retreat of the sea from the surrounding region, while some of the marine strata that once rested beneath the Cretaceous sea have been elevated to their present positions more than 10,000 feet above sea level. Strata containing marine fossils of Eocene age at altitudes of 10,000 feet in the Alps, 11,000 in the Pyrenees and 19,000 feet in the Himalayas, indicate the elevation of those mountain ranges since early Tertiary time. The Coast Range along the Pacific coast of the United States involves marine strata of Miocene age, indicating elevation in late Tertiary time, their growth perhaps continuing to the present time. The Andes in Bolivia were elevated to 13,500 feet since Miocene or Pliocene time. That earth-crust movements in the coastal region from Alaska to Central America are still in progress seems evident from the numerous earthquakes.

Mountains have come and gone. They have risen from the ocean shores, pushed their summits high into the clouds, ruled over the landscapes and controlled the climates of continents, then dwindled away. So has it been through the long ages of the past, so shall it be through ages yet to come. Where gigantic mountains now rear their heights, the ocean tides may some time roll again and build new formations, as in the past. Where great rivers now pile up their sediments on deltas, filled with shells and bones of animals and leaves of trees, mountains may some time slowly rise, exposing along their flanks the strata and fossils that record some small portions of the earth's history, just as similar strata have been elevated in the long ago, for us to study in the present era.

The direct influence of mountain ranges in the production of scenic effects is so obvious that it insistently stares one in the face. Their indirect effect through their influence upon climate, thus determining the character of the vegetation of large regions, is not so obvious, but just as certain. Moist air currents from the Pacific, intercepted by the coastal ranges of California and Washington, precipitate the greater part of their moisture on the western slopes, leaving the eastern slopes and Great Basin arid and consequently barren except along the few stream courses. It is said that the rainfall on the windward side of some of the islands of the Hawaiian group is from four to thirty times as great as on the leeward side, owing to the interception of the prevailing winds by the mountains. Where mountains rise to sufficient altitudes, greatly decreased temperature and increased precipitation in the form of snow, drifted by the ceaseless winds of such heights, result in snowbanks and glaciers, which add greatly to the variety and striking beauty of mountain scenery. The flanks of mountains are more or less covered with vegetation, including shrubbery and trees, in some instances of quite different types from those of the surrounding plains, just as the vegetation of the moist and dry sides of a mountain range differs. In many of the higher mountains the streams are clear and sparkling, abounding in trout, with numerous lakes and waterfalls, the forests are inhabited by deer, the rocky regions by chamois, ibex, mountain sheep or mountain goats, which, with the wonderful scenery and cool climate, combine to make delightful summer resorts for careworn men and women.

"If thou art worn and hard beset
With sorrows that thou wouldst forget,
If thou wouldst read a lesson that will keep
Thy heart from fainting and thy soul from sleep,
Go to the woods and hills."
LONGFELLOW.

"O! there is sweetness in the mountain air,
And life that bloated ease can never hope to share."
LORD BYRON.

The Volcano

"The dread volcano ministers to good:
Its smothered flames might undermine the world."
YOUNG.

VOLCANOES and their activities are among the most spectacular of geological phenomena. The most sudden changes in the scenic aspect of any portions of the earth are those occasioned by volcanic eruptions, in marked contrast with Nature's usually slow and quiet methods. The terrific explosion that tore away the upper 4,000 feet of Krakatoa in 1883, produced an ocean wave that engulfed 30,000 people, and hurled into the air volcanic dust in such quantities as to affect the atmosphere around the world, causing the hazy skies and the beautiful red sunsets and sunrises that attracted so much attention immediately afterwards in Asia, Europe and America.

The eruptions of Pelée and Soufrière, in the Windward Islands, about twenty years ago, at their maximum forced into the air 48,000,000,000 cubic feet of dust and stone-laden steam per hour. Some of the fragments thrown high and far weighed a thousand tons. The finer dust was carried to a height of five or six miles. Hot blasts swept down the mountain sides, destroying buildings and all vegetation in their paths and taking 30,000 human lives. Volcanic ash was showered over the islands, accumulating in places to a depth of thirty feet. Flows of volcanic mud coursed down the slopes and valleys.

Numerous eruptions of Taal volcano, in the Philippine Islands, have been recorded within historic times. Vivid accounts of twelve such events are found in the Spanish chronicles, but the terrific bombardment of 1911, with its desolating and destructive effects, is fresh in the memory of even the younger generation. One explosion at that time was heard over an area 600 miles in diameter, and destroyed the lives of 1,400 people. Mud and volcanic ash was spread over an area of 1,200 square miles, the finer dust having been carried much farther. It was accompanied by earthquakes, with a displacement along two fault lines of from one to two yards.

Mount Katmai, 7,500 feet high, in Alaska, was the scene of an eruption in 1912. The mountain was half blown away, forming a crater nine miles in circumference and 3,000 feet deep. The first explosion was heard 750 miles away. Volcanic ash aggregating five cubic miles in volume, was showered over all the east end of the Alaska peninsula and some of the islands. Complete darkness due to ashes in the air settled over an area of several thousand square miles, and continued for sixty hours at a point 100 miles distant. Dust fell for a distance of 900 miles from the volcano, and fumes were reported from Puget Sound, 1,500 miles away. Earthquakes added to the terror of the people. The deposits of ash reached a depth of more than twenty-five feet in some places. The detritus filled lakes or changed their shore lines and forced streams to seek new channels.

Beds of pumice a foot in thickness floated on the sea and impeded navigation until cast up on the beaches by the waves and tides.

The eruption of Tamboro, on the island of Java, in 1915, was perhaps one of the most severe on record. It was followed by darkness for three days at a distance of 300 miles, dust fell over an area of 1,000,000 square miles, ash accumulated to a depth of two feet 800 miles away and the explosions were heard for 1,000 miles. It is estimated that the material ejected aggregated from twenty-eight to fifty cubic miles.

An eruption in Iceland in 1783 ejected a greater flow of lava than any other known anywhere during the historic period. The ash destroyed crops in Scotland, 600 miles away, and plants were blighted by sulphurous fumes in Holland, more than 1,000 miles distant.

Various eruptions about the Mediterranean have wrought great destruction to life and property because they occurred in populous regions. Vesuvius is well known throughout the world and the burial of Pompeii is a familiar fact to all civilized nations. The changes wrought by these and many other eruptions, especially in the destruction of vegetation and alteration of topography, have been very marked, partly temporary and partly permanent. Vegetation soon extends over devastated ground, though in revegetation the invading plants or plant societies may be of very different types; and who can restore the summits of Krakatoa and Katmai?

As this paragraph is being written, in February, 1919, word comes of tremendous changes in progress at the volcano of Kilauea, Hawaiian Islands, a "monumental rising of a vast lava column." "Over the southwest brink, a wide stream of glistening lava is sluggishly flowing in the direction of Ka'u Desert, not with the spectacular cascading of the southeastern flows of last March, but with a steady, stealthy gliding, which gains ground slowly at its face, but which piles up into tremendous masses from its source forward. The effect is a peculiar one, for as the lava seeks the hollows and fills up the irregularities, it is producing an almost perfectly smooth sweep of floor over a mile in circumference. This condition will be stable for several hours, and then, as though the superincumbent weight had become insupportable, vast sections of the plateau will sink forward, releasing from beneath gigantic torrents of crimson and orange liquid lava, which surge upward and roar away over the adjacent surfaces, causing them in their turn to collapse and provide more pyrotechnics upon a tremendous scale, and repeating the process over and over again." (Science, XLIV, 1919, p. 189.) Thus do volcanoes continue to transform landscapes by flows of mud and lava, destroying everything that stands in their way, by deep sheets of showered ashes, and by the building and destruction of volcanic cones, just as they have for many ages. The Miocene formation of Florissant, Colorado, is a deposit of volcanic mud and ash, embedding hundreds of species of fossil plants and insects, thus informing us of ancient volcanic eruptions and in part revealing the life of that period.

True volcanoes are cones of lava, volcanic ash, pumice and rock fragments built up about their vents, usually rather symmetrical in outline. They are not scattered promiscuously over the earth, but occur only in certain regions known as volcanic districts. One such district extends along the western side of South and North America to Alaska, thence through Asia to the East Indies and Sumatra. Many of the volcanoes of that district are extinct or have been inactive for a long period, but many are still active. Ten of them in Central America have been in eruption within the past century. At least twelve active volcanoes are known in continental Alaska and a larger number in the Aleutian Islands. In the United States proper Lassen Peak, California, has been ejecting steam, mud and lava within the past few years. Probably between 300 and 400 volcanoes of the world may be considered active, while many others have been active so recently in geologic time that they may burst forth again, as did Vesuvius in 79 A. D., and Lassen in 1914, after long quiescence.

Volcanoes are themselves very important elements in scenery, quite apart from their influence through explosions, ash showers, lava flows and other phenomena, or the spectacular temporary displays during eruption. Some of the best known mountains in the world are active volcanoes, such as Vesuvius in Italy and Fujiyama in Japan. This is also true of some of the most imposing mountain peaks in the world, reaching an altitude of 23,000 feet in the Andes, the highest mountain in South America. Cotopaxi, in Ecuador, is 19,000 feet high.

Orizaba, in Mexico, is 18,000 feet and Popocatepetl 17,000 feet. Kilimanjaro, in Africa, is nearly 20,000, and Kenia more than 17,000. Haleakala, Island of Maui, Hawaiian Islands, extends only 10,000 feet above sea level, with a crater six or seven miles in diameter, while Orizaba, in Mexico, with an altitude of about three and a half miles, has a crater only 3,000 feet in diameter. Some islands in the ocean are the tops of volcanoes, sometimes reaching an altitude of 30,000 feet above their bases on the ocean floor, but extending only a few hundred or thousand feet above the water. Such a volcanic summit is Stromboli, north of Sicily, projected 3,000 feet above the sea and in frequent eruption. St. Vincent Island, the site of the volcano Soufrière, eighteen miles long and eleven miles wide, with an altitude of 4,000 feet above sea level, is composed of lava and tufa dipping away in all directions to the sea. Volcanic islands, such as Boglosoff, in Bering Sea, have been formed by eruptions within historic time. Other volcanoes are entirely submarine, pouring out their lavas upon the ocean floor, perchance building up cones that may some day reach the surface and form new islands.

Volcanic mountains resulting from eruptions of past geologic ages are abundant. Mounts Rainier and Baker, in Washington, Mount Hood, in Oregon, and Mount Shasta, in California, are excellent examples. Many others occur in regions not now within volcanic districts. A fine example is the San Francisco Mountain group, in Arizona, the highest and most prominent mountain peaks in the southwestern United States, the highest point being

12,562 feet above sea level and 5,700 feet above the surrounding tableland. Crater Lake, in Oregon, one of the most striking bits of scenery in America, occupies an ancient volcano truncated by the caving in of the crater floor and portions of the walls.

Many mountains are the result of erosion of thick sheets of lava (Fig. 77). Others are remnants of lavas which have come up through vents or crevices, and been left standing above the surrounding country by the destruction of the softer surrounding rocks (Figs. 47, 94). Many of the larger flows of lava have come from long fissures through the rocks, rather than from volcanic cones or necks. The most recent large fissure flow likely occurred in Iceland.

The most extensive flows within the historic period are not at all to be compared with those of ancient times. This may not at all indicate that intense volcanic activity is a thing of the past, but merely that we are passing through a period of comparative quiescence, such as have frequently occurred in geologic times.

An Upper Cretaceous flow or series of flows of lava in Asia covers 200,000 square miles, with a depth of from 4,000 to 6,000 feet in places. The Tertiary lavas of Washington and Oregon cover about the same area, with a maximum depth of at least 4,000 feet. The Newark system of igneous sheets extends from Nova Scotia to South Carolina, a distance of about 1,000 miles, with a width of 200 miles. A deposit of columnar lava in Alaska is 3,000 feet thick. Perhaps the best-known, though by no means the largest, lava formation in the United States is that of the Palisades, on the Hudson.

Where the columnar structure produced in cooling is very pronounced, the lava exposed by weathering is often very picturesque, and has frequently been compared with the pipes of a pipe organ. Fine examples of this are the Giant's Causeway in Ireland, the Devil's Tower in Wyoming (Fig. 94) and rugged points of the Cimarron district in Colorado.

Long after a lava flow the heat from deeply-buried ejecta may continue to modify the landscape. Thus the hot waters of Yellowstone Park that produce the many columns of steam, bubbling springs, spouting geysers and other striking phenomena, are constantly and rapidly building up the wonderful travertine terraces by the deposition of lime perhaps leached from the Mesozoic formations far below the surface and brought up by the hot water. It is generally believed that the source of heat is buried lava which has not yet had time to cool. Similar phenomena are observed in New Zealand and Iceland, and recent widely-read magazine articles have made quite familiar to the general public, as well as to scientists, the Valley of the Thousand Smokes in Alaska.

Though intense volcanic activity is only an occasional temporary episode in the usual orderly progress of Nature's processes, yet the local scenic effects are likely to be the most conspicuous elements in regions subjected to great activity, and the aggregate influence upon the scenery of the world at large assumes enormous proportions. If such scenery as the Palisades, Crater Lake, the numerous active volcanoes and thousands of extinct volcanoes, together with the lesser lava and tufa cliffs (Fig. 36), were eliminated, many of the most striking views would be lost to the traveller, and many an interesting region would be monotonous and uninteresting.

Geology and Vegetation

"A primrose by the river's brim,
A yellow primrose was to him,
And it was nothing more."
WORDSWORTH.

THE primrose, beautiful in itself, nodding in the passing breeze, adds much to the charm of the landscape, however indifferent one may be to its significance as part of a well-balanced, closely interlocking system of cause and effect. To the thoughtful lover of plants, it is something more than a beautiful flower. It is an incident in a beautiful and interesting story. If it follows the course of its ancestors, it is not the end of the story, which began in the long ago and will continue to future generations. The primrose is on the river's brim because a long series of events followed one another in orderly succession, in response to Nature's eternal, unchanging, interacting laws. Long ago — so long no man knoweth the lapse of time—geological agencies deposited mud and sand on the delta of an ancient river. The deposit, accumulating to great thickness, hardened into rock in the course of time. The rock was tilted, folded and elevated above sea level. It was attacked by frost, chemical solution and the attrition of rushing, sand-laden waters. It was broken into fragments. The fragments were ground up and reduced to soil. Rising mountains, intercepting moist air currents from the ocean, brought rain to the land and sent the river coursing to the sea. The soil was carried down the river in flood time and deposited in its valley as the water receded. The stream, in its meandering, cutting at its retaining wall, formed the present bank. Meantime, the primrose family, in response to biologic laws, came into existence, was differentiated into genera and species, each reproducing after its kind — yellow, white, purple, rose, lilac and other colors. The seeds were passed on from generation to generation, keeping the species from destruction. Thus the line of life was continued down to the time the tiny seed fell upon the river's brim, sprouted, sent its roots down after the nurturing moisture of the soil, put forth its leafy laboratory for the sunlight to use in the manufacture of chlorophyll and the production of stem and petal, and spread its petals to the breeze to ripen its fruit, just as its ancestors have done for a thousand thousand generations.

Dreary indeed is the landscape without trees, shrubs and herbs. That soil conditions, both physical and chemical, are largely responsible for the character of the plants of any locality is a matter of common knowledge. Soil is a geological product. Some plants seek sandy soil or gravel, some prefer loam, some grow only on rocky ledges. The great influence of ground moisture and evaporation is also familiar to all. We subconsciously associate dry prairies with hard prairie grasses, cacti and other plants that seek dry soil; swampy places with more succulent plants — cat-tails and sedges (Fig. 78); moist

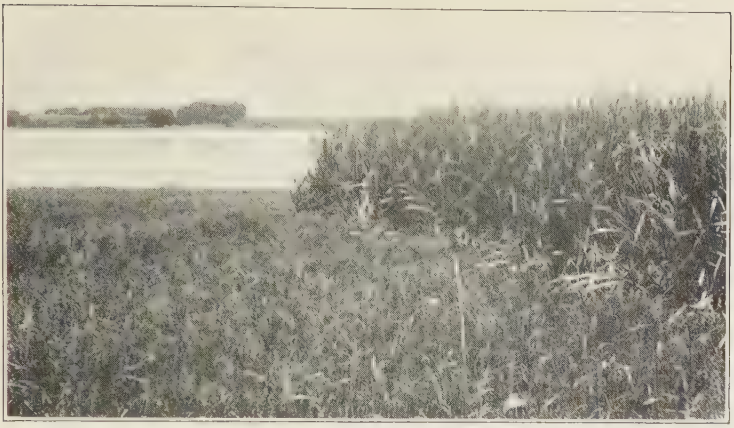

Fig. 78 — Cat-tails in a marsh at the edge of a lake.

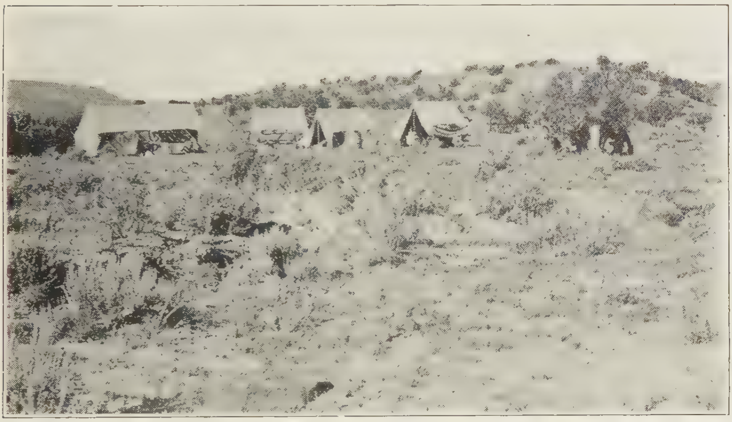

Fig. 79 — Sage-brush on the flat, with dwarf cedars on the rocky hill in the background.

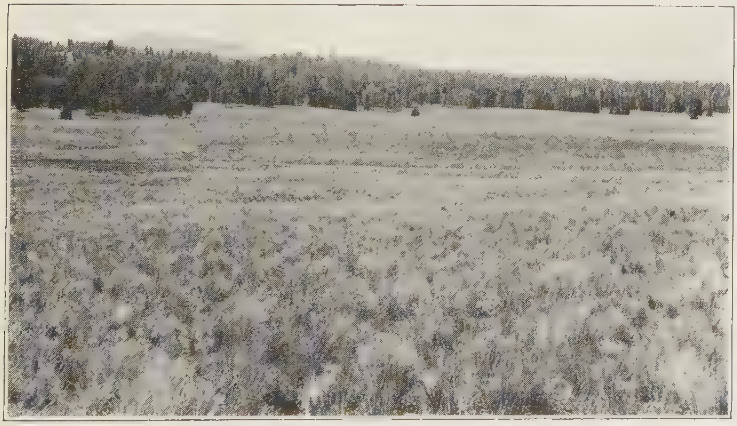

Fig. 80 — Conifers on rocky hills, with a treeless valley in the foreground.

meadows with buttercups; and shady spots with certain kinds of ferns. All these conditions are provided directly or indirectly by geological processes.

The control of vegetation by its geological environment is naturally more evident in regions where the general climatic conditions limiting the growth of plants are most severe, with small areas of marked contrasts, but nowhere is that control altogether absent. In portions of the semi-arid West the sage-brush flats (Fig. 79) give way to rabbit bush in more alkaline soils. In many parts of the world it is possible to trace geological formations by the character of the vegetation. Certain groupings or associations of plants are recognized by botanists as characteristic of the serpentine barrens of southeastern Pennsylvania. It is said that native Kentucky blue-grass is confined to the area in northern Kentucky where Silurian dolomitic limestones outcrop, while Johnson grass adheres rather closely to Cretaceous soils of the Southern States. In portions of the southern Rockies the rock pines, pinyon pines and cedars are usually found where the rocks are covered with little or no soil (Figs. 80, 81, 82, 84), so that geologists who have ridden out into almost treeless valleys to small clumps of evergreen trees (Fig. 81), expecting to find rock outcrops, have not been disappointed. The trees send their roots down into crevices of the rocks, thus obtaining a secure hold to enable them to resist the fierce winds, and are sustained by storm waters accumulated in the cracks. Certain species of lichens grow only upon the bare faces of sandstones, and often give to cliffs their colors — green, red, brown and yellow. Very beautiful concentric lichens are found on the rocks of some localities (Fig. 88). According to McGee, the relation of forests to soil in northeastern Iowa is so definite that generally, though not always, the "irregularly sinuous boundary of forest and prairie land coincides exactly with the boundary between loess and drift," so as to give the observer the impression of a "universal forest covering in a region of prevailing prairie land."

In most of these cases the controlling factor is probably not chemical, but physical. In some cases it is the direct result of the influence of rock formations and soils upon the distribution of ground water.

On the western treeless plains (Fig. 87) almost every watercourse has its narrow fringe of shrubs, willows and cottonwoods (Figs. 83, 85, 86), ornamenting and protecting its banks, following the meanders of the stream and never getting beyond reach of the seepage waters. Even intermittent drainage channels, usually dry, are often filled with Cretaegus and other trees and shrubs not found on their divides. Clumps of brush may thrive at the foot of a shrubless slope (Fig. 86), because the shrubs get a little more of the run-off from rains and melting snow. Where the topography is favorable for snowdrifts the additional moisture, continued later into the spring and early summer, results in vegetation of different character from that of windswept ridges free from snow. A slight difference in the direction or angle of a slope in an arid region, making a difference in the rate of evaporation because of the angle of the sun's

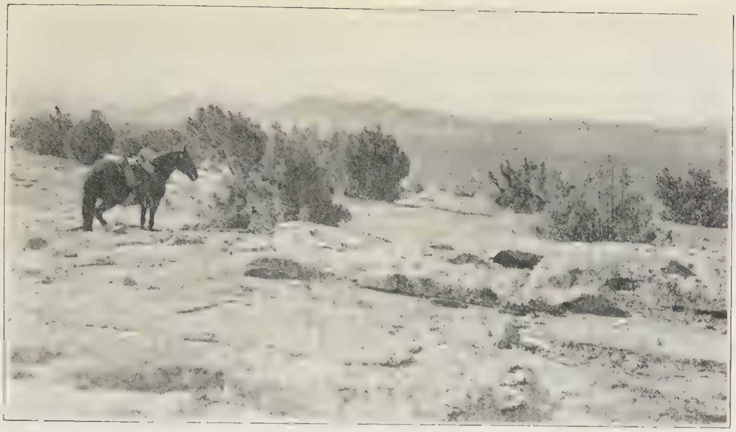

Fig. 81 — Cedars and pinyons on a sandstone exposure in a sage-covered valley.

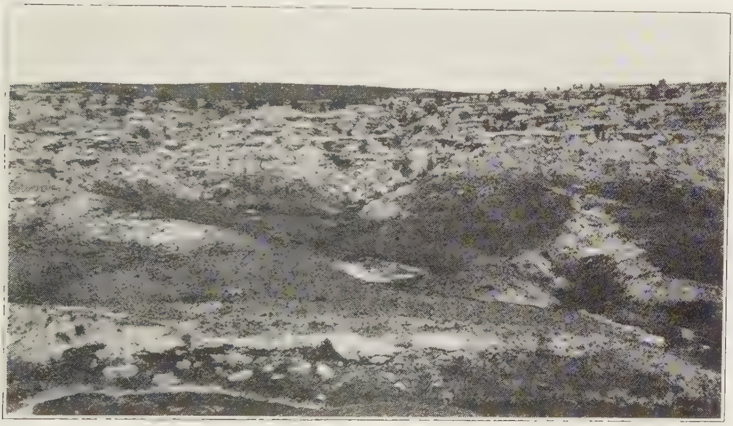

Fig. 82 — Pine-clad sandstone ledges in an otherwise treeless prairie region.

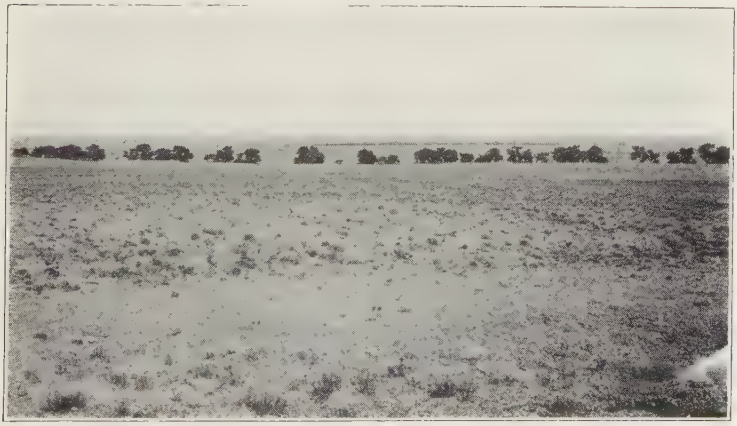

Fig. 83 — Willows and cottonwoods along a stream in an otherwise treeless prairie region.

rays with the plane of the slope, produces a marked effect upon the character and thriftiness of the plants. The same is none the less true in more moist regions, though not so obvious in its results.

The desert of Sahara and its oases, in Africa, so strongly contrasted in their scenic beauty and scientific interest, are the products of geological conditions and processes. So, too, are the Great Dismal Swamp, in Virginia and North Carolina, and the Irish peat bogs, though quite unlike both desert and oases in their appearance, and resulting from different geological conditions and processes.

The vegetation of mountain ranges, varying at different altitudes because of difference in temperature, precipitation and evaporation, add greatly to the variety of mountain scenery. Particularly noticeable is the marked and often very abrupt change in the vegetative mantle of the mountains at timberline (Fig. 89), a dense cover of trees giving way to slopes almost entirely devoid of trees and shrubs. A similar abrupt change from dense forests to treeless areas occurs along the margins of many lakes (Fig. 67), especially ancient glacial lakes which are rapidly filling with vegetation.

In addition to these purely local vegetative conditions due to geological environment, so profoundly affecting landscapes, the general climatic conditions vitally important to plant life are also largely controlled by geological phenomena, such as the distribution of land and water and the relation of mountain ranges to prevailing winds. The very distinct influence of general climatic conditions upon the distribution of plants is within the knowledge of even the children. The giant cactus of the hot, arid southwestern United States is wholly unsuited to the cool, moist climate of Puget Sound basin. It is an extreme example of adaptation to climatic conditions. The palms of subtropical Florida would not survive the rigors of a winter in Maine. The alpine plants of our higher mountains would not thrive in a climatic environment suitable for the tropical flora of Panama.

With a knowledge of the relation of climate to vegetation, the fossil plants, supplemented by fossil animal remains, enable us to ascertain some of the geologic changes of climate. The association of fig leaves, palm leaves and other subtropical plants in the Cretaceous rocks of Colorado and adjacent states, and in Alaska and Greenland, informs us of a former much milder climate in the northern part of the northern hemisphere than now prevails, and enables our imagination to picture those lands as they must have looked when clothed with vegetation so different from that now found there. In the coal beds of the Carboniferous Age are found giant horsetails (Calamites), "seed-bearing ferns," Lepidodendrons and Sigillarias, telling of moist, mild conditions, which doubtless gave to the landscapes of the eastern United States an aspect quite different from that of any landscapes now in existence (Figs. 4, 5). The Permian Glossopteris flora of the southern hemisphere and the giant cycads of the Jurassic and Cretaceous in the northern hemisphere, gave to certain regions in those by-gone

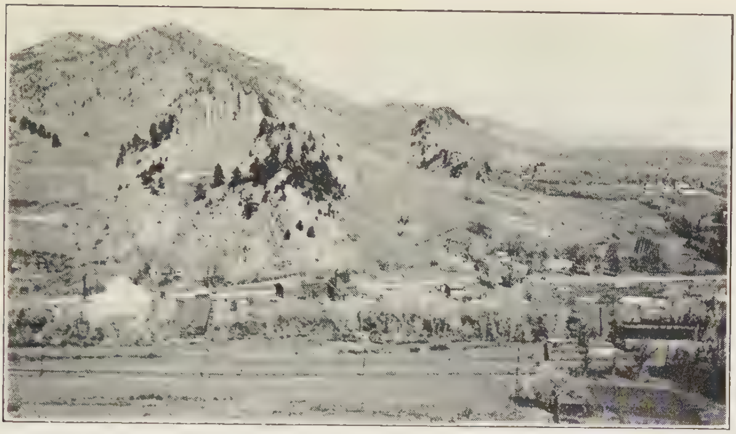

FIG. 84 — Pines clinging to rocky ridges, cottonwoods along stream.

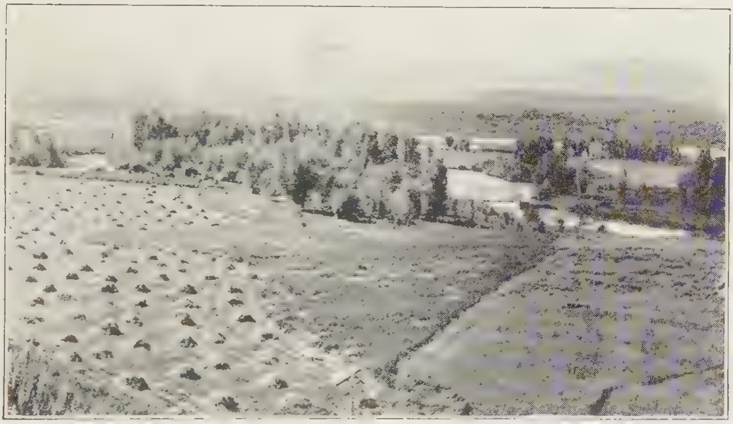

FIG. 85 — Cottonwood grove on a river bank.

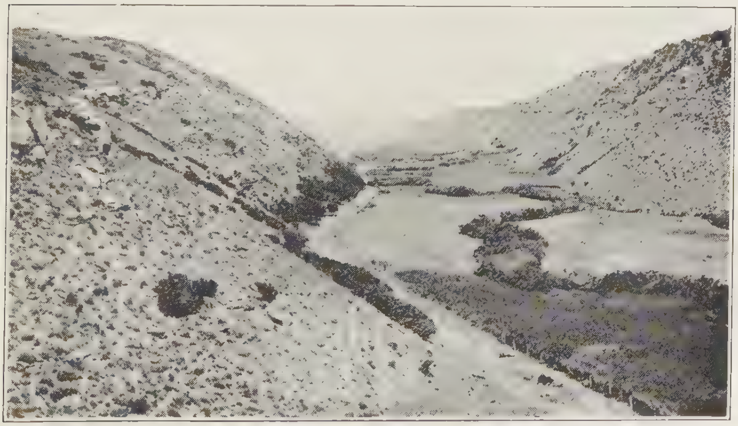

FIG. 86 — Willows along a creek bank in the flat bottom of a partly-filled V-shaped, stream-cut valley, and shrubbery at the foot of the slope, where it is more moist than above or below.

ages landscapes wholly different from any that now exist or could exist in those regions.

Not only do geological conditions affect vegetation, but, in compensation, plants react upon their geological environment and must be numbered among geological agencies. We have seen how the expansive power of growing roots of trees aid in the cracking of solid rocks (Fig. 34) and how vegetation is an active agency in the filling of lakes (Figs. 67, 78). In the filling of lakes plants follow one another in rather definite order, depending somewhat in any region upon the general climate and present soil conditions. In large portions of the temperate zone sedges push out into the lake, building up the soil in hummocks extending above the surface of the water and preparing the way for other plants. As the spaces between hummocks are filled, forming solid, well-watered land, a fringe of shrubby willows along the shore often follows the sedges, grasses follow the willow fringe, shrubbery follows the grasses and forest trees follow the shrubbery, thus all often forming well-marked zones, slowly advancing from all sides toward the center of the lake. This, of course, only happens in shallow lakes or shallow portions of deeper lakes.

It is not improbable that bacteria and other low forms of plant life directly or indirectly assist in the decomposition and disintegration of rocks and hence in the production of soils for the use of the higher plants. On the other hand, low forms of plant life undoubtedly aid in the deposition of lime from hot springs, as is so notably shown in the great terraces of Yellowstone Park (Figs.

7, 18), and form important deposits in ponds and elsewhere. Soil bacteria perform an exceedingly important work in the fixing of nitrogen in the soil for the use of the higher plants, and thus have a marked influence upon landscape, yet they are so tiny that they may only be seen by the aid of a microscope of high power. The beautiful microscopic diatoms, "jewels of the plant world," constitute a large part of some formations, thus assuming an important role in the preparation of rocks and soils for the making of landscapes, and, by forming oil, are partly responsible for the present "oil-derrick topography" of portions of California and elsewhere. Algae and other low plants are considered the source of a large part of the oil in the oil shales found exposed in great cliffs of western Colorado and eastern Utah, whose finely-laminated strata, like the leaves of a book, have given to one large area the picturesque name "Book Cliffs." Thick beds of coal, one of the most important of the economic geological products, were derived from the rank vegetation which formed part of the landscapes of certain past geological ages, notably the Carboniferous and Cretaceous (Fig. 4). Traversing civilized lands, with tall smokestacks pouring forth columns of coal smoke, smelters and factories of various sorts breaking the sky-line, coal-heated homes, stores and office buildings adding to the atmospheric haze, railway trains and electric cars driven by power derived from the burning of coal passing swiftly in various directions, and clouds of coal smoke rising from steamships in the harbors and on the broad seas, who can doubt the share of coal plants in the produc-

Fig. 87 — A treeless plain.

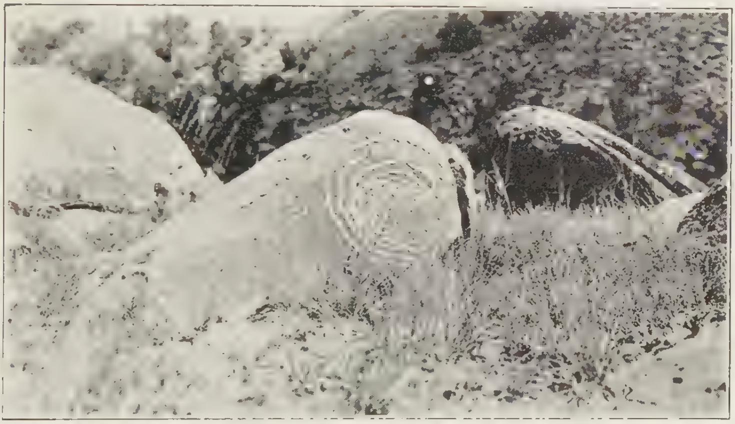

Fig. 88 — A concentric lichen growing on sandstone.

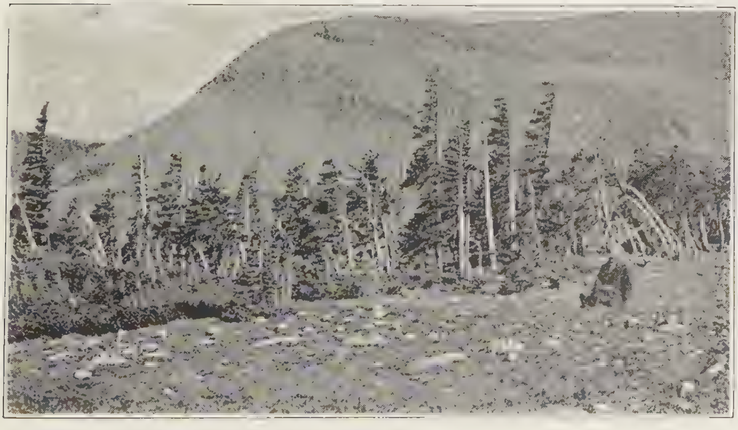

Fig. 89 — "Wind timber" in the higher Rocky Mountains, showing effect of prevailing winds on the branches.

tion of present scenery? The profound scenic influence of those ancient plants does not stop even with the scenery of the past and present, but projects itself into the future. The carbon of which coal is chiefly composed is not destroyed in burning. It passes into the atmosphere and at some future time, proximate or remote, will in a large measure be again taken up by plants and thus incorporated into the landscapes of the future.

The most important geological function of plants is in connection with erosion. As a rule erosion is very much less active in a moist region, with its heavy vegetative cover, than in an arid region, where vegetation is scant and finds difficulty in obtaining and retaining a foothold. The interlocking roots of plants form a mat and bind the soil together, while the foliage breaks the force of falling raindrops and hailstones, thus preventing storm waters, rushing down the slopes, from carrying away the soil. Likewise plants prevent the drifting of sand before the wind (Fig. 29). So important is this that certain species are now known as "sand-binding" plants, and their planting is recommended on wind-swept areas, where shifting dunes threaten to ruin farms. They not only prevent soil from being carried away by wind and water, but they catch and hold soil blown or washed from elsewhere, thus aiding in building up deposits of importance. The removal of forests in some regions has resulted in disastrous erosion, and gravel and sand from deforested slopes has been carried out and deposited over farms in the low-lands, to their ruin. The disturbance of the vegetative mantle on steep slopes by unskilful methods of agriculture and by over-grazing has in many cases resulted in their speedy denudation by severe storms. Much of the clear-cut erosion in arid regions and the striking and characteristic land forms resulting therefrom (Figs. 27, 28, 30, 31, 32, 33, 39, 40, 41, 93), are due to the lack or scantiness of vegetation. Hence the presence or absence of plants, and their relative abundance, are important factors in determining the character of the landscape, not only because of their own varied forms and colors, but because of their influence upon topography.

The wind as a geological agent is shown in various ways. The forms resulting from aeolian erosion are usually quite different from those produced by aqueous erosion. The sand dunes are of aeolian erosion, affected in various ways by sand-binding plants (Fig. 29), but a most interesting phase of the influence of wind upon landscape is its effect upon trees. Where strong winds blow from one direction most of the time, as is generally the case in high mountains, and often also on exposed points along the seashore, they cause the trees to lean to the leeward or to project all their branches out on that side (Figs. 89, 90, 91). On wind-swept slopes and ridges this sometimes produces grotesque and astonishing effects. The same phenomena may be seen in many valleys and on plains, though the effect is not so pronounced. It frequently enables an explorer in an unknown region to know at a glance the direction of the prevailing winds. The horticulturist in such regions sets out his young trees with a lean to the windward to offset the action of the

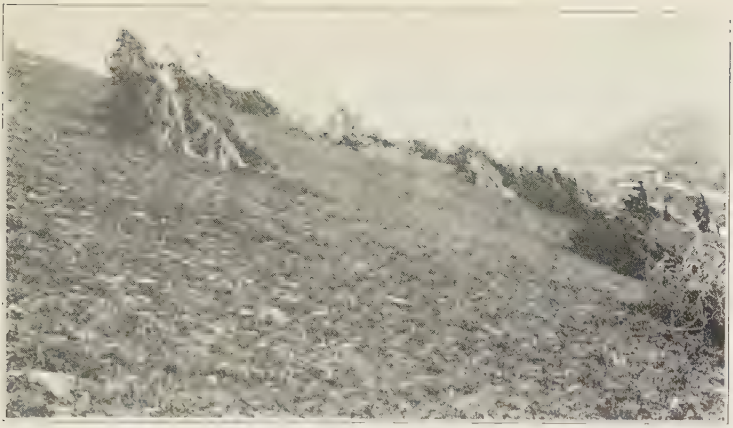

FIG. 90 — "Wind timber" in the Rocky Mountains.

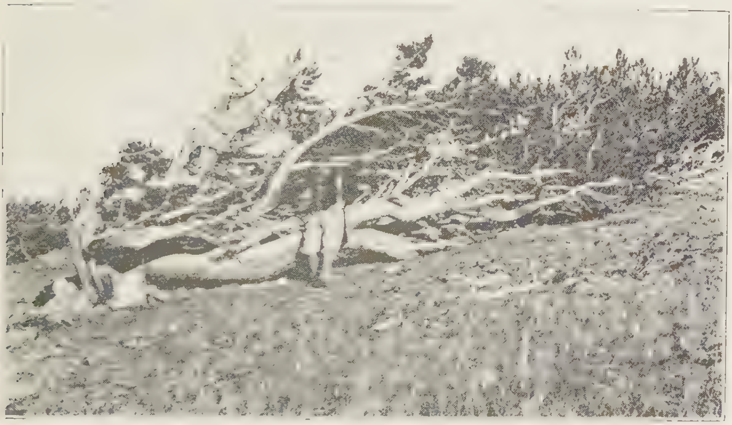

FIG. 91 — "Wind timber" in the Rocky Mountains, showing combined effect of high winds and heavy snows.

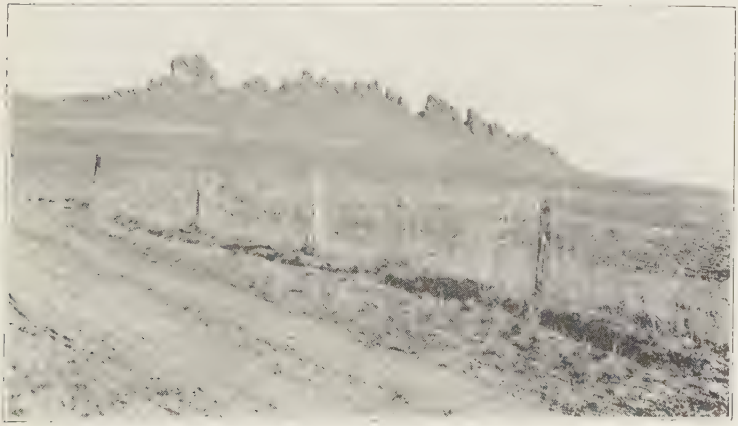

FIG. 92 — Sandstone ledge tilted to a vertical position and then dissected by erosion, the softer adjacent strata eroded away.

wind. Where snow is heavy it often bends young trees to the ground in the direction in which they lean and holds them in that position through the winter. When the snow melts they are unable to recover their former positions and so continue to grow in a more or less prostrate position to maturity and old age (Figs. 90, 91).

In these and many other ways are shown the interactions and interrelations of vegetation and geology in the production of scenery. In all their numerous ramifications the laws and phenomena of Nature react one upon another. Nowhere may a sharp line be drawn between the varied manifestations of natural law; nowhere may we say of this or that particular manifestation that it affects no other manifestation. The laws of physics and chemistry, the phenomena of geology and biology, meet at innumerable points, all contributing to the beauty of every landscape, and as the combined effect of all these things,

> "The lands are lit
> With all the autumn blaze of goldenrod;
> And everywhere the purple asters nod,
> And bend, and wave, and flit."
>
> HELEN HUNT.

Geology and Animal Life

The Eagle.

"He clasps the crag with hooked hands,
Close to the sun in lonely lands;
Ring'd with the azure world he stands,
The wrinkled sea beneath him crawls;
He watches from his mountain walls,
And like a thunderbolt he falls."

TENNYSON.

WHAT landscape is complete without the flowers, trees and shrubs to adorn it and the animals to enliven the view? Whether we have consciously formulated the mental concept or not, the influence of geological phenomena upon the distribution of birds, mammals, butterflies and other forms of animal life is known to all. We think of eagles as nesting on ledges of lofty cliffs, of condors soaring high above mountain crests, of chamois among ragged crags and peaks, of ptarmigan gathering their food from the edges of glaciers. The zoologist mentally associates redwings and bitterns with marshes, bobolinks with meadows, kingfishers with brooks and rivers, towhees with shrubbery, chickadees with trees, lark buntings with prairie lands, elephants with jungles, hippopotami with rivers. The hunter associates water-fowl with ponds, lakes, rivers and the sea, mountain sheep with snow-clad peaks, pronghorn antelope with treeless plains, where bison once

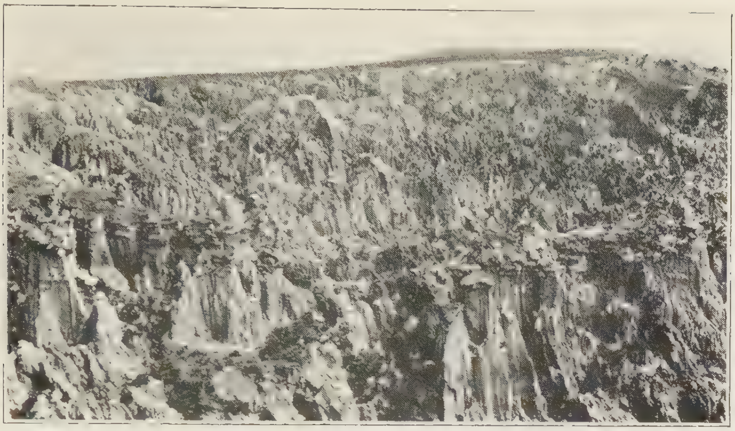

FIG. 93 — "Hell's Acre," Wyoming, showing pinnacles caused by storm-water erosion of soft strata partly protected by thin, hard layers and not protected by a good vegetative cover.

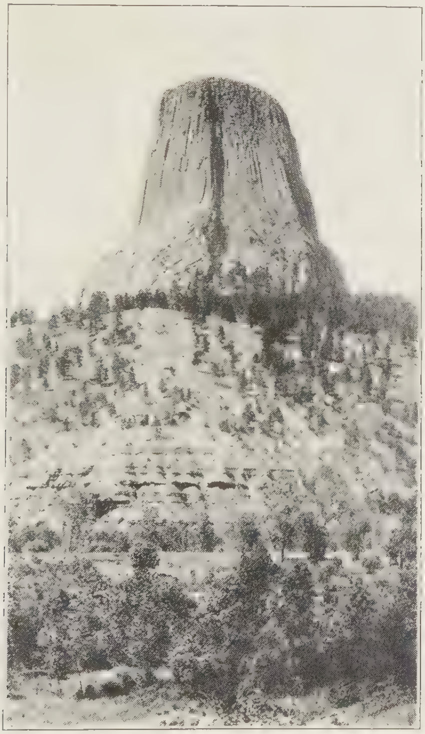

FIG. 94 — "Devil's Tower," Wyoming, volcanic rock with vertical columnar structure, exposed by the erosion of soft surrounding formations. By courtesy of the United States Geological Survey.

roamed in countless herds. The fisherman sees in the brook's ripples the feeding places of trout, and in ponds the lurking places of other species. The painter enlivens his scene by the outlines of swallows skimming over the surface of the pond in search of mosquitoes, gulls sailing over the bay, ducks and coots swimming on the surface of the lake, a startled deer in the forest glade, or cattle resting beneath the shade of spreading elms. The naturalist knows that some species dwell in secluded ravines, others frequent open plains, others delight in sunny mountain slopes, others mount to the tops of lofty mountains, others bathe in the placid waters of ponds or swift waters of rivers, while others breast the ocean waves. The ornithologist seeks the remarkable water ouzel along the banks of dashing mountain torrents, the nuthatch among the trees, the junco in weedy fields. The farmer's boy knows that the swamp, with its cat-tails, provides a nesting site for the redwing and yellow-headed blackbird.

Everywhere the controlling factor is partly or wholly geologic—obviously so where the eagle seeks its nesting site in a mountain precipice, or a lake with its bordering marsh furnishes feeding grounds and nesting sites for ducks, or a mountain stream provides proper habitat for the ouzel. It is no less true, though indirectly so, where the immediate controlling factor is the character of the vegetation, for geologic phenomena in one way or another exercise a tremendous influence upon vegetation. Geologic processes prepare the proper soils, proper slopes, proper climates and proper drainage for the various kinds of trees and other plants (see Frontispiece).

Geologic phenomena affect even the seasonal migrations of birds. Along the seashore certain species in their northward and southward movements proceed from headland to headland, just as other species do on plains bordering north-south mountain ranges. Also distinct migrations up and down the steep slopes are noticed where high mountains rise abruptly from plains.

As with plants, not only does the geological environment greatly influence animal life, but animals in many ways react upon the geological environment. The life and work of the beaver is a beautiful illustration of this reciprocal relation. The home of the beaver is determined by geological conditions—a stream flowing in a valley wide and flat enough for the construction of a pond, whose soil and moisture conditions produce a fringe of trees suitable to the purposes of this interesting animal. Then the beaver proceeds to modify his environment—to transform the surrounding landscape. He gnaws down, cuts into convenient lengths and carries away trees for food and for the construction of his dam and dwelling-place. The dam he extends across the stream to back up and spread out its water into a pond or lake in which to build his winter home. There are thousands of such ponds scattered over North America where the beaver was so abundant until, with the coming of white man's commerce, the value of his skin became the cause of his undoing. The beaver ponds adorn many of the high valleys of the Rocky Mountains, where the animals are still not uncommon, and affords refuge for young trout until they are large enough to care for themselves in the swifter waters of the streams.

The activity of earthworms in moving soil has long been known. They are continually bringing fresh earth to the surface, the total amount of soil thus moved by all the worms in the world being very large, and to some extent their burrows aid in aerating the soil. In the eastern United States, where moles are abundant, their activity in burrowing, loosening and moving soil is well known, though the enormity of the total result is but little realized. Grinnell has recently called attention to the work of numerous species of burrowing rodents in the western United States and its relation to soil fertility, water conservation and the growth of vegetation. He estimates that there are one billion of these animals in California alone. From a calculation based upon considerable evidence he declares that in Yosemite Park the gophers raise 8,000 tons of earth an average height of eight inches per annum. Hence the aggregate amount moved by all the burrowing species over the whole area from the Mississippi to the Pacific is almost beyond conception, yet this total must be multiplied by the thousands of years during which the animals have been burrowing, in order to get the grand total of their work. Where the animals are very abundant the annual turn-over of soil must be almost equal to the rather sketchy and shallow plowing sometimes indulged in and perhaps equal to the amount moved by erosion during the same period. The soil brought to the surface by the animals is thus made subject to more rapid weathering, which releases fresh mineral food required by plants. The freshly-raised earth buries other vegetation, which decomposes and helps enrich the soil, just as vegetation turned under by the plow does. The loosening of the soil on wild lands where it is not stirred by the plow counteracts the packing due to the tramping of horses and cattle, thus admitting air to the soil, which is essential to plant growth. The burrows and the looseness of the fresh soil brought to the surface permits the land to quickly absorb rainfall and thus conserve it in regions were precipitation is deficient. Consequently, though these rodents become so destructive in many cultivated localities that measures must be taken for their destruction, it is doubtful whether their wholesale destruction in uncultivated regions is altogether advisable. At any rate, there can be no question that the work of such animals has a noteworthy indirect effect in the preparation of soil and thus influences scenery in some localities, while such structures as the prairie-dog "hills" of our western plains add an unusual element to the prairie landscape.

There can be no doubt that in many places the work of the burrowers facilitates erosion, by loosening the soil so that it may be more easily washed away by storms. However, they are not the only animals that thus act indirectly as erosive agencies. There are many localities in dry regions, where the vegetative cover is scant, that now present barren, rocky slopes because of the excessive pasturage of cattle, and more particularly of sheep. The slopes were once covered with a thick coat of soil, upon which grew grass and various herbs and small shrubs, which protected the soil from erosion. The animals trampled the soil during dry seasons, loosening it, meantime cropping the vegetation so close that it no longer protected the soil from beating rains. Then active erosion began and in a few years denuded the slopes, causing damage which will require centuries for Nature to repair, just as the match or cigarette of the careless smoker destroys forests which will require centuries for Nature to restore, and by removing the forest cover facilitates erosion which denudes the slopes.

Birds and mammals in various ways distribute the seeds of plants, thus helping in the production of trees, shrubs and herbs that bind the soil, act as conservators of water and aid in various ways in the building of new formations, while preventing the destruction of the old. Insects aid in the pollination of flowers and so in the maturing of seeds, thus forming an important link in those geological processes which affect or are affected by vegetation, while the larger butterflies, moths and dragonflies, flitting about the plants, add to the beauty of the landscape.

The work of earthworms in the soil in many ways affects the vegetative cover. It is estimated that in England alone the worms move 40,000 pounds of soil annually, so that the aggregate for the whole world must be tremendous. In fact, it is the minute forms of life that are most important geologically and indirectly exercise the greatest influence upon landscape, not the great animals—not the dinosaurs, elephants and whales. By their very numbers they accomplish that which larger animals, fewer in number, could not do. The disastrous work of aphids, locusts and ants in the destruction of plants is well known. Not so well known is the fact that in the tropics such small creatures as ants and termites greatly influence the topographic conditions. Their tunnels and burrows open up the soil and soft rocks to various atmospheric influences; their huge mounds break the level of the surrounding country; while their destructive inroads upon the vegetation still further transform the landscapes. Clark says, "Brazil is one great ants' nest." Severiano de Fonseca says, "the ant and the different kinds of termites own the land" in portions of Paraguay. Sampaio estimates Brazilian ant colonies at from 175,000 to 600,000 individuals each. Bates says their attacks actually compelled the evacuation of one town by its human inhabitants. All this prepares us for Branner's statement that in some places the ant mounds occupy from a fifth to a third of the ground, some reaching a height of sixteen feet, with a basal diameter of about fifty feet, supporting trees a foot in diameter. The structures of the white ants, or termites, nearly as high, but more slender, add variety to the scene. It is estimated that in Brazil alone 60,000 pounds of soil are moved by ants annually. In the temperate zones ant-hills are seldom more than two or three feet in diameter and a foot or so high, as in western and southwestern United States, while the great majority are only a few inches in diameter. Consequently their work is not geologically so important and does not so strikingly modify the scenery as in the tropics. Nevertheless, in consideration of the enormous number of small colonies scattered over the earth, the aggregate amount of material moved by ants throughout the world in the course of centuries is exceedingly large.

Great coral reefs and the picturesque atolls and coral islands in the tropics, have been built by myriads of tiny animals still engaged in the work. The bluffs of chalk in England and many limestones elsewhere entering into the composition of scenery, are composed chiefly of shells of minute foraminifera and mollusks. Certain siliceous deposits of scenic importance owe their silica to the minute animals, radiolaria, and the minute plants, diatoms.

As with fossil plants, fossil animals also tell the story of geological changes of climate, which must have been accompanied by marked scenic changes. The record must be read with caution and with knowledge of the real facts, to avoid incorrect conclusions. The presence of fossil mammoths, related to the Asiatic elephant, in the far north, may easily lead one to picture such regions with a mild climate during Pleistocene time. The discovery of an extinct species in Siberian ice, the flesh in good state of preservation and portions of the skin intact, proved that it was clothed in a thick coat like that of the Arctic musk-ox. Other facts indicate that the other mammoths, including those that lived in the United States, were likewise prepared for resistance to intense cold, and they are thus represented in the most accurate restorations.

If, then, added to the influence of animals upon geological phenomena, reflected in scenic effects, the birds, butterflies, deer and other animals help to enliven the landscape and by their presence bring pleasure to the observer, then the geological processes by which their abiding places are produced and maintained must be reckoned as factors of importance in the final adjustment of scenery. To rob the landscape of its mammals, its singing birds, its buzzing bees, its fluttering moths and butterflies, would be to rob it of some of its chief attractions.

Geology and Civilization

"Not all the winds, and storms, and earthquakes, and seas, and seasons of the world have done so much to revolutionize the earth as man . . . has done since the day he came forth upon it, and received dominion over it."

BUSHNELL.

THE works of man make or mar landscapes throughout the civilized world. The rail fence or log cabin (Fig. 74), fitting into its surroundings, may seem a part of the natural scenery. The rambling, weathered old mill, with its water wheel, on the river bank, is not out of place. The painted farm house, with its barbed-wire fence, may be in harmony with its waving fields and grassy pastures. Even towns and villages, grown old, the homes half hidden by ancient trees, may afford delightful vistas.

"How often have I paused on every charm,
The sheltered cot, the cultivated farm,
The never-failing brook, the busy mill,
The decent church that topped the neighboring hill,
The hawthorn bush, with seats beneath the shade,
For talking age and whispering lovers made."

GOLDSMITH.

On the other hand, the works of man may but mar the landscape, as, with regard only for utility, he builds without reference to beauty or harmony, with no provision for trees, or shrubs, or flowers, to mask the ugliness of construction. His unsightly telephone poles stand out as the most conspicuous objects in the foreground of otherwise delightful views of natural scenery. Many of his bridges are scenic monstrosities.

In more primitive periods the locations of homes and communities of men have been determined to a very large extent by geological phenomena (Fig. 36). The old mill was located where the fall of the stream gave sufficient power to turn its machinery. The log cabin was placed by a spring or brook that provided cool water for domestic use, in the edge of a forest that furnished logs for its construction and fuel for its hearth. The farm house is built where the soil is suitable for agriculture. The western cattle ranch exists because of the geological environment, including water and wide areas of grass land for the stock. The Indian camp or village was usually beside running water—spring or stream. Wells are the result of crowding, forcing portions of the population away from the open water. The village and town have grown up where topographic features are favorable to commerce. The town of Niagara Falls owes its existence partly to the scenic grandeur of the Falls, and its modern growth to the industrial use of its power. Many of the larger cities are great because they are located where harbor facilities are ample and ingress and egress easy—because of geological conditions that make for profitable navigation. New York is New York because of its harbor and geographic position· The Thames and its geographic position make London what it is. San Francisco's growth is due to the bay and Golden Gate. Chicago, now one of the world's great railroad centers, whose commerce has transformed prairies and swamps into tall buildings and factory smokestacks, had for her original transportation line the Great Lakes, the traffic of which still continues to add to her growth and prosperity. New Orleans and St. Louis were founded when the Mississippi was the great inland transportation route, before railroads spread their network over the land. The building of each city has transformed the landscape of many square miles of territory. The very character of the buildings has until recently been determined by the material close at hand. In a forested area, wood was the material of construction. Where wood was scarce and clay abundant, brick was the material most used. The ancient pueblo and cliff dweller used stone where it was plentiful and easily worked into shape, or sun-dried adobe brick where stone was not easy to get or use and adobe was convenient. Hence his structures were the direct result of geological environment. He even excavated caverns in soft tufa cliffs (Fig. 36), to add to the dimensions of his houses, or occupied natural caves (Fig. 28), and took advantage of wind-blown caverns in the massive sandstones to shelter his cliff dwellings. The early settler on the treeless plains found prairie sod a good substitute for other material, and built therewith substantial homes with warm, thick walls to resist the howling blizzards. It will be noted that nearly all these materials are of direct geologic origin, and the others are made possible by geological conditions—soil, moisture, climate, etc. With the dawn of the railway age geologic environment ceased to be so important as it once was, though in many ways it is still a controlling factor. The onward march of exploration and settlement no longer closely follows the water. Where deep wells, made possible by modern machinery, fail to produce water for the inhabitants, it may be hauled in tank cars over the railroads. Food, fuel, clothing and building materials may be transported over barren plains and into deserts, so that towns may be built wherever the need for them is found. Even so, many of the new towns far from sources of supply for the necessities of life, are the direct result of geologic conditions, as, for instance, mining towns where coal and ore are found, quarry towns in the vicinity of building stone, oil towns where oil may be obtained, and agricultural towns on fertile soils far from fuel, building materials, clothing and water.

Wherever civilized man appears, he changes the scenic aspect of his surroundings. He erects buildings and bridges, constructs railroads, wagon roads, fences, telephone and telegraph lines. He destroys forests here and plants groves there. He sows grains where grass lands were and sets out orchards where hazel brush grew. He drains swamps and lakes. He constructs reservoirs, on sites determined by geological conditions, to impound water for domestic, power and irrigation purposes. He builds dikes to reclaim tide flats from the sea and to prevent rivers in flood from spreading over their valleys. He builds jetties at the mouths of rivers to control the currents and prevent the filling of the channels. He builds breakwaters into the sea to protect harbors, and retaining walls along the shores to stop the intrusion of the waves.

He dredges harbors for their improvement and with the dredgings builds up adjacent flats, making dry land where rolled the ocean's tides. He digs wells in the desert and around them makes oases. He digs canals and builds pipe lines and cement conduits to conduct water over dry mesas, converting them into fertile fields. He introduces trees unknown to the natives, which transform the landscapes, as Lombardy poplars introduced into Utah and Idaho and eucalyptus in California have done. By exterminating animals he has wrought great changes in some instances, as in the destruction of the American bison, which once gave to the Great Plains a distinctive appearance now unknown anywhere. On the other hand, he has also defied the balance of Nature by introducing plants and animals, sometimes with disastrous results, sometimes to his advantage and to the advantage of his scenic surroundings. He has set out plants and adopted other methods for the control of drifting sand, to prevent the shifting of sand dunes. In deforesting and plowing steep slopes and cutting into them for wagon roads, he has opened the way for rapid erosion, which has worked disastrous changes in the landscapes. He has connected oceans and seas with canals, through which move great ships. Not content with affecting landscapes in these and scores of other ways, he sends canal boats and steamers coursing over the waterways and sailboats over the bays, thus adding to or detracting from the interest of the views. He has transformed seascapes by his ships plowing through the waves, while his lighthouses at night send their beams far asea. In all, or nearly all, these things, one may clearly detect the geologic element, sometimes the controlling factor, sometimes merely incidental, influencing or influenced by man's activities and everywhere changing the scenic aspect of regions inhabited by civilized nations.

The works of man which have transformed landscapes and affected geologic conditions locally, are sometimes overwhelmed and destroyed by geologic agencies and processes. Thus ancient Pompeii and Herculaneum were buried by the ejecta from Vesuvius, Galveston was wrecked by a tidal wave, buildings have often been undermined by waves and toppled into the sea, and many a farm house has floated away on a river flood.

Topographic features produced by geologic processes, such as rivers and mountains, have formed the boundaries and battlegrounds of nations, protecting the weak from the strong, directing or controlling migrations, and preventing the mixing of nations which might otherwise have resulted in partially eliminating racial prejudices.

> "Lands, intersected by a narrow frith,
> Abhor each other. Mountains interposed
> Make enemies of nations, who had else,
> Like kindred drops, been mingled into one."
>
> Cowper.

In so controlling the destinies of man, topography has to a marked degree controlled his activities in the modification of his environment. The irregular outlines of European countries, and even of their minor subdivisions, represent the influence of topography upon early history. The same element in the early history of the United States is reflected in the boundaries of the Eastern States, while the newer Western States, laid out by use of surveyor's transit and chain, present angular outlines, their boundaries mostly coinciding with lines of latitude and longitude. Even in portions of these newer states, where mountains are rugged and abrupt, their crests usually form the boundaries of counties, while the more level counties are angular in outline, their boundaries running to cardinal points of the compass. Blackwelder has pointed out the influence of geology, particularly the relations of plains to mountains, upon the history and civilization of the vast area of China, affecting the "habits, occupations and even mental traits" of a people numbering many millions. The geology, topography and whatever affects the history and civilization of a nation, reacts upon the landscape through its influence upon the constructive and destructive activities of the people.

In Conclusion

"There is a pleasure in the pathless woods,
There is a rapture on the lonely shore,
There is society where none intrudes,
By the deep sea, and music in its roar;
I love not Man the less, but Nature more,
From these our interviews, in which I steal
From all I may be, or have been before,
To mingle with the universe and feel
What I can ne'er express, yet cannot all conceal."
BYRON.

UPON all the surface inequalities brought into existence by erosion, deposition and the folding and faulting of strata, their broken outlines adorned by trees, shrubs and flowers, with their varied hues and tints, plays the ever-changing light, momentarily emphasizing or bringing into relief first one detail and then another. Thus the view changes with the season, the time of day and the shifting of the clouds, and variety lends enchantment to the view. Neither mount nor vale long remains the same, bathed in sunlight, or with clouds hanging low upon the mountains or fogs drifting in from the sea, as lights and shadows come and go, varying each moment and hour with the constantly varying angle of light. The sun in midsummer rises from a rosy horizon, its rays at a low angle lighting the trees, and rocks, and hills on their eastern surfaces, projecting long shadows to the westward and spreading a golden glow over all.

"The east is blossoming! Yea, a rose,
Vast as the heavens, soft as a kiss,
Sweet as the presence of woman is,
Rises, and reaches, and widens, and grows
Large and luminous up from the sea,
And out from the sea, as a blossoming tree."
JOAQUIN MILLER.

The sun mounts higher and reaches the zenith, shedding its noonday glare full upon the land, shortening the shadows and optically flattening the landscape. It begins its decline into the west, lighting the scene from a new direction and swinging the shadows to the eastward. Then come the afternoon clouds, fleecy islands floating in the sea of blue sky, their shadows flitting over hill and dale, meadow and field.

"Beautiful cloud with folds so soft and fair,
Swimming in the pure, quiet air,
Thy fleeces bathed in sunlight, while below
Thy shadow o'er the vale moves slow."
BRYANT.

The storm gathers. The clouds thicken and darken until the sky is overcast, the patches of high lights and shades blending into a neutral whole. Lightning plays and thunder rolls. Then comes the deluge.

"And sometimes too a burst of rain,
Swept from the black horizon broad, descends
In one continuous flood. Still overhead
The mingling tempest weaves its gloom, and still
The deluge deepens; till the fields around
Lie sunk and flatted, in the sordid wave.
Sudden the ditches swell; the meadows swim.
Red, from the hills, innumerable streams
Tumultuous roar, and high above its banks
The river lift; before whose rushing tide,

Herds, flocks, and harvests, cottages and swains,
Roll mingled down; all that the wind has spar'd
In one wild moment ruined; the big hopes
And well-earned treasures of the painful year."
THOMSON.

The storm passes on, leaving the air freshened, the foliage washed and every gully bearing away its flood. The sun's rays, broken into their primal elements by myriads of water prisms of opposing clouds, are refracted back to the observer in the colors of the rainbow spanning the eastern sky.

"Far up the blue sky a fair rainbow unroll'd
Its soft-tinted pinions of purple and gold;
'Twas born in a moment, yet quick as its birth,
It had stretched to the uttermost ends of the earth,
And fair as an angel, it floated as free,
With a wing on the earth and a wing on the sea."
MRS. WELBY.

The shadows lengthen, push out from western hills into the valley, the evening glow is in the sky. As the evening haze deepens into night,

"Touched by a light that hath no name,
A glory never sung,
Aloft on sky and mountain wall
Are God's great pictures hung.
How changed the summits vast and old!
No longer granite-browed,
They melt in rosy mist; the rock
Is softer than the cloud;
The valley holds its breath; no leaf
Of all its elms is twirled;
The silence of eternity
Seems falling on the world."
WHITTIER.

Then the moon, rising as a huge, red orb from the eastern horizon, its light whitening as it mounts, traverses the sky, with weird effect as its thin, silvery rays struggle through the leaves, shining full upon exposed spots and seeking to penetrate the gloom of dark recesses. Its shadows, long in the early evening, shorten as it moves toward the zenith, shift to the opposite direction and lengthen as it descends the western sky, until, dipping below the horizon, it leaves the earth dark and forbidding, lighted only by the feeble rays of twinkling stars.

As the view varies from hour to hour, day and night, so, too, it varies from season to season, as the angle of light changes from day to day with the movement of the points of sunrise and sunset northward and southward along the horizon, while the days lengthen and shorten. In temperate zones especially does the landscape change with the procession of the seasons. The freshly-plowed fields and bare boughs of early spring soon give way to verdure as the grain sprouts and the trees and shrubs put forth their leaves. Flowers and the blossoms of fruit trees lend variety to the color scheme. With the advancing season cherries and berries redden the orchards and gardens. The grain ripens and moves in golden waves before the breeze, while apples take on red and golden hues. The grain is harvested and stands in shocks and stacks about the fields. The shocks are hauled away and marketed, leaving only the stubble to tell the story, while the corn is cribbed and the apples are picked, barreled and stored for winter use. The foliage of trees and shrubs assume the brilliant autumnal colors. Soon the leaves are swept away, leaving the landscape bare and brown. Then come the winter snows and ice, whitening the earth, obliterating landmarks, locking up streams and putting the land to sleep, until the warmth of advancing spring brings back life to the frozen world and prepares the way for another cycle of planting, growing and harvesting.

So to him who with Nature holds communion, she speaks a different language for each hour, each day, each season. If his sojourn be confined to the haunts of men, he hears her language in the cultivated fields and city lots. If his travels carry him into the wilderness, he hears her voice in every rock and rill, and sings from valley or mountain top:

"I love Thy rocks and rills,
Thy woods and templed hills,
My heart with rapture thrills
Like that above."

As we consider all the phenomena and natural processes combined in the creation of a beautiful landscape, and in its variation from day to day, season to season, age to age, in response to laws, eternal, unchanging, "in the beginning impressed upon matter by the Creator,"

"In contemplation of created things
By steps we may ascend to God."
MILTON.

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